ELECTRONIC ASSIGNMENT COVERSHEET

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Fighting Against Global Tuberculosis

I. Executive Summary

This report presents a comprehensive analysis of tuberculosis (TB) trends from 1991 to 2013, focusing on its prevalence, incidence, mortality rates, and the impact of HIV co-infection. The study leverages business analytics tool to visualize the data captured from worldwide to uncovers key insights that can inform policy decision makers and improve TB detection, treatment, and prevention efforts globally.

The findings from the study indicate that Southeast Asia and Africa bear the highest TB burden, with high rates of TB-HIV co-infection exacerbating mortality, particularly in sub-Saharan Africa. While TB-related deaths have declined over time, cases involving HIV co-infection continue to have a significantly higher fatality rate, emphasizing the need for integrated healthcare interventions. The study also reveals a strong correlation between TB incidence and HIV prevalence, highlighting the necessity of improving early detection and targeted treatment strategies.

Beyond epidemiological trends, the report also examines the socioeconomic determinants of TB, revealing that economic growth and human development play crucial roles in reducing TB cases and deaths. Countries with higher GDP per capita and Human Development Index (HDI) scores tend to have lower TB prevalence and mortality, whereas low-income nations struggle with higher disease burdens due to weaker healthcare infrastructure.

Wealthier countries generally achieve higher TB detection rates, preventing further transmission, while low-GDP nations face challenges in diagnosing and treating cases efficiently. The findings suggest that a holistic approach—integrating healthcare improvements with socioeconomic policies—is essential for effective TB control. Strengthening healthcare investments, improving data collection methods, and prioritizing TB-HIV treatment programs in high-burden regions are key recommendations.

By utilizing data analytics and evidence-based decision-making, this report provides actionable insights to support governments, health organizations, and policymakers in their efforts to eliminate TB as a major global health threat.

II. Introduction

Tuberculosis (TB) remains a major global health challenge, ranking among the deadliest infectious diseases worldwide. Each year, millions of new TB cases and deaths are reported, with the burden disproportionately affecting low- and middle-income countries where healthcare access, early detection, and treatment services are often inadequate. The airborne transmission of TB allows it to spread easily, making its prevention and control a pressing public health priority.

One of the most significant factors contributing to the TB epidemic is its strong association with HIV. Individuals living with HIV are at a much higher risk of developing active TB due to their compromised immune systems, and TB remains the leading cause of death among HIV-positive individuals. This co-epidemic is especially severe in regions with high HIV prevalence, such as sub-Saharan Africa, where TB and HIV fuel each other's spread.

Effective TB control efforts must incorporate integrated HIV prevention, screening, and treatment strategies to curb both infections. Strengthening healthcare infrastructure, expanding access to antiretroviral therapy (ART), and improving TB diagnostics are critical steps toward reducing the global burden of TB and its impact on vulnerable populations.

Key Epidemiological Terms

To support the following comprehensive analysis, it is essential to understand three fundamental epidemiological metrics:

- **Prevalence:** The total number of existing cases (both new and old) of a disease in a population at a specific time. It reflects how widespread the disease is.
- **Incidence:** The number of new cases of a disease occurring in a population over a defined period. This metric helps measure the rate at which new infections or cases emerge.
- **Mortality:** The number of deaths caused by a disease in a population within a given time frame. It indicates the severity of the disease and its impact on survival.
- **Death (TB cases):** The actual number of individuals who have died as a caused of TB. It counts the number of total fatalities from TB cases within a given period.

These metrics are crucial for assessing the extent, spread, and fatality of diseases, helping guide public health interventions and policy decisions.

III. Problem Statement

Tuberculosis (TB) remains one of the deadliest infectious diseases, with a resurgence in the late 1990s and early 2000s driven by multiple factors. Complacency following early control successes led to weakened TB programs, while drug-resistant **Mycobacterium tuberculosis** strains made treatment more challenging. Urbanization and increased population density facilitated transmission, while economic recessions strained healthcare systems, reducing funding for TB prevention and treatment, particularly in developing countries. These factors collectively worsened the global TB crisis, highlighting the need for sustained intervention. Several critical factors have contributed to the persistence and resurgence of TB, including:

1. **Complacency in TB Control**: Following early successes, there was a reduction in focus on TB control, which allowed the disease to resurface.
2. **Emergence of Drug-Resistant TB**: The development of antibiotic-resistant strains of *Mtb* has complicated treatment and increased mortality rates.
3. **HIV/AIDS Co-Infection**: The co-infection of TB and HIV/AIDS has intensified the global burden, particularly in regions with high HIV prevalence, such as Sub-Saharan Africa.
4. **Urbanization**: Increased population density and mobility have accelerated the transmission of TB, particularly in urban settings.
5. **Economic Recessions**: Economic downturns, particularly during the late 1990s, resulted in significant underfunding of healthcare systems, undermining TB treatment and control efforts.
6. **Slow Progress in Declining TB Incidence**: The rate of decline remains slow (1.1% annually), with some regions continuing to report rising cases, particularly of drug-resistant TB.
7. **Stigmatization**: The perception of TB as a disease predominantly affecting the poor has led to the underestimation of its risk in middle- and high-income populations.
8. **Ongoing Global Health Threat**: Despite global efforts to control the disease, TB remains a major public health challenge due to co-infection, drug resistance, and insufficient global responses.

Stigma surrounding TB downplays its risk in wealthier nations, despite its impact on immunocompromised individuals. The disease disproportionately affects low- and middle-income countries, where disparities in incidence, mortality, and treatment persist. HIV/AIDS has intensified TB vulnerability, especially in Sub-Saharan Africa, while drug resistance and healthcare barriers hinder control efforts. Despite medical advancements and global programs, TB remains a major public health threat, highlighting persistent regional inequalities.

IV. Stakeholders

In 2014, the WHO implemented the challenging program called End TB strategy to lead and support global initiatives aimed at achieving a world free from tuberculosis, with no deaths, disease, or suffering caused by the illness (Global Tuberculosis Programme, 2025). A fundamental principle of the World Health Organization (WHO) End TB Strategy is the cultivation of robust collaboration with civil society. Stakeholders engage in these strategic calls to establish strong policies and supportive frameworks.

Below table is a list of direct and indirect key stakeholders to transform policies, mobilizing resources, and creating strategies to address tuberculosis (TB).

Direct Stakeholders	**Rational/Actions**
World Health Organization (WHO)	Actively develops global TB policies and guidelines to eradicate tuberculosis. Enhance and maintain long-term investments through collaboration with critical stakeholders. Support in research funding and partnerships for TB eradication. Monitors and supervises TB trends to guide the development of global health strategies.
Local Ministry of Health and Communities	To identify local issues associated with the response to tuberculosis. To establish appropriate and effective community engagements strategies for local contexts and illustrate their integration into national policies and strategic decision making.
Healthcare Staffs (doctors, nurses, lab technician and health care workers)	To diagnose and treat the TB patients and formulate the treatment plans.
Hospitals, Clinics, Laboratories and Diagnostic centers	To arrange resources allocation and provide facilities for TB care and treatments such as conducting TB testing, drug resistance.
TB patients and survivors	Actively participate in treatment, provide mental support, and advocate for policy improvements.
Non-governments organizations (e.g., APCASO based in Bangkok, GCTA based in India, TB Vaccine Advocacy Roadmap)	Engage with local communities to raise awareness about TB services and treatment guidelines through targeted campaigns.
TB research Institutions	Research on drug-resistant TB, vaccines, and treatment strategies
Pharmaceutical Companies	Develop on TB drugs, vaccines and diagnostic tools
Epidemiologist	The expertise of epidemiologists plays a critical role in studying TB transmission patterns, identifying risk factors, and assessing the effectiveness of control measures. By analyzing disease trends and evaluating public health interventions, they provide evidence-based recommendations for TB prevention, early diagnosis, and treatment programs. Their insights help shape policies, optimize resource allocation,

	and improve healthcare strategies to reduce the global TB burden.
Global Burden Disease (Independent Advisory committee)	Advise on policy implications and strategic interventions. Facilitate collaboration between global health organizations and governments.

Indirect Stakeholders	**Rational/Actions**
Government policymakers	Collaborate with WHO, local MOH and establish TB policies, allocate funds and set public health priorities.
International Funding organization (e.g. global fund, world bank)	To support TB treatment and prevention programs financially.
Employers, workplaces, educational institutions, public	Advocate for public health policies and support employees affected by TB. Educate on TB prevention and conduct public health research. Adhere to TB awareness guidelines and promote community engagement.
Media and Advocacy Groups	To raise awareness, educate the public, and announce policy changes through the media.
Technology and Innovation Companies (e.g., digital health profile, advanced diagnostic tools)	Develop and enhance diagnostic tools such as portable devices, to enable early TB detection and monitoring in rural or remote areas through innovative technology.
Native-born population	native-born populations are classified as vulnerable groups due to the significant health and economic impacts of TB. Understanding the gaps in TB prevention and treatment among these populations is crucial for developing targeted interventions.

V. Objective or goals of analysis

The primary objective of this project is to comprehensively analyze and understand the dynamics of tuberculosis (TB) from the years 1991 to 2013, utilizing business intelligence tools, particularly Tableau, as a key enabler to uncover critical insights that can strengthen TB outcomes on a global scale.

This project seeks to:

1. **Examine Regional and National TB Trends:** Pinpoint geographic hotspots and regions with high TB burdens, that require intensified focus and intervention in the areas of TB case detection, prevalence, incidence, mortality, and death.
2. **Analyze Epidemic Trends**: Investigate TB epidemic trends in high-burden countries over 13 periods. Assess whether there have been significant improvements in reducing the risk of TB over time in specific regions or countries and identify the factors influencing these changes.
3. **Predict Future TB Trends**: Predict TB trends in the next 5–years for those high Burden regions.
4. **Examine the relationships between TB and HIV**: Assess whether there are significant correlations between TB incidence, prevalence, mortality, and death rates in relation to HIV co-infection.
5. **Strengthen TB prevention, diagnosis and treatment strategies** by understanding patterns and allocating resources efficiently.
6. **Analyzing the Relationship Between Economic Growth and TB Burden:** Assess how GDP per capita influences TB prevalence and mortality rates, helping to determine if economic development directly contributes to disease reduction.
7. **Evaluating Human Development Factors and TB Outcomes:** Investigate how HDI components such as healthcare access, education, and living standards impact TB incidence and mortality.
8. **Examining Healthcare Efficiency in TB Detection and Control:** Compare TB case detection rates across different economic and human development levels to assess the effectiveness of healthcare systems in diagnosing and managing TB cases.

VI. Report Primary Findings

This section analyses key Epidemiological patterns in tuberculosis (TB) from 1991-2013, examining prevalence, incidence, mortality, and deaths associated with both HIV-positive and HIV-negative populations across six regions: Africa (AFR), Americas (AMR), Eastern Mediterranean (EMR), Europe (EUR), Southeast Asia (SEA), and Western Pacific (WPR).

SEA recorded a median TB prevalence of 407 per 100,000 population and an incidence rate of 238 per 100,000, while AFR accounted for 94% of HIV-related TB mortality and a significant proportion of overall TB deaths.

A. HIV Case Detection

During the 23-year period from 1991 to 2013, a total of 349,275 TB cases were detected, with 16% of these cases being HIV-positive. The highest number of cases was found in the Eastern Mediterranean Region (EMR), particularly in **Iraq**, with an average of 139 cases and 13 % of individuals being HIV-positive. In the African region, the highest HIV co-infection rates were observed in Zimbabwe (87%), Uganda (75%) and Malawi (74%).

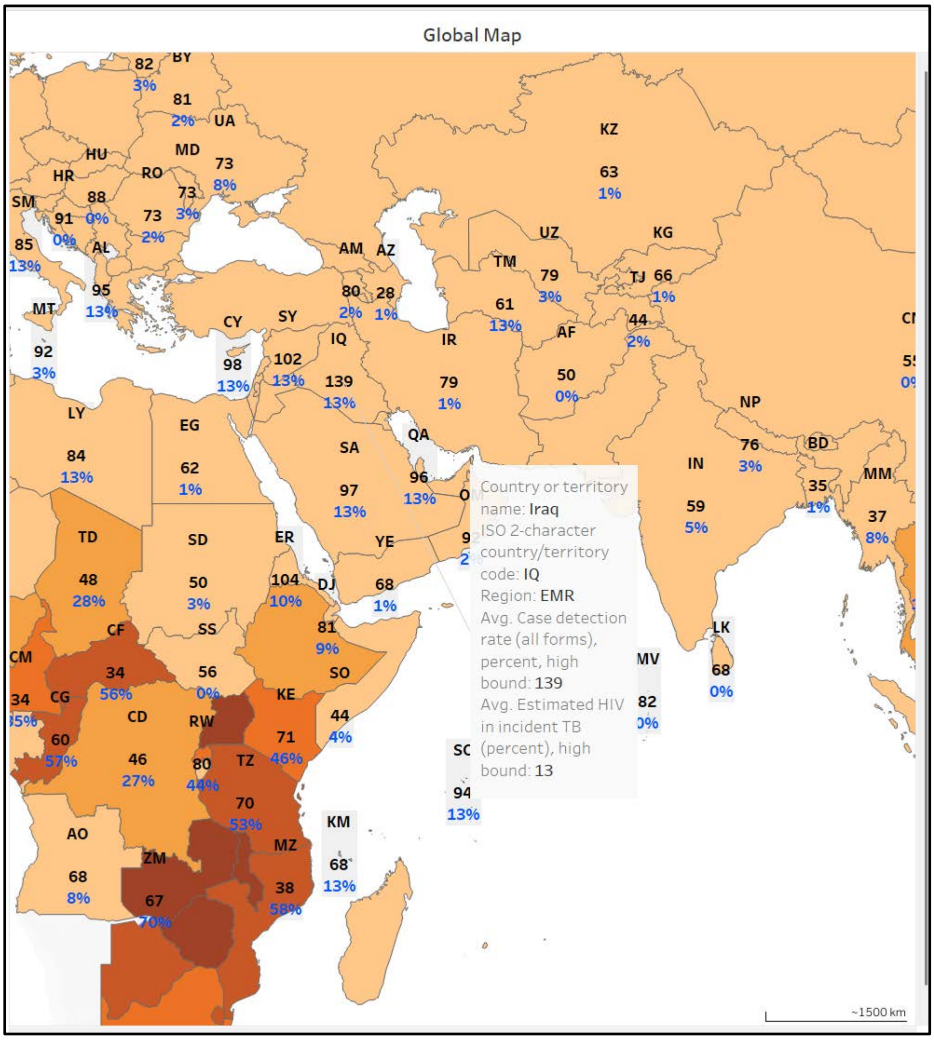


Figure 1: Global Map of Case Detection by HIV%

1) Highest TB-HIV burden across regions

Across the six regions, the total average of HIV-infected TB cases was **9,540.** The regions with the highest TB burden were in **Africa (AFR)**, where **50.47%** of TB cases were higher risk associated with HIV. In contrast, in the **Americas (AMR)**, **21.33% (WPR) and 11.68%** of detected TB cases were linked to HIV-infected living populations.

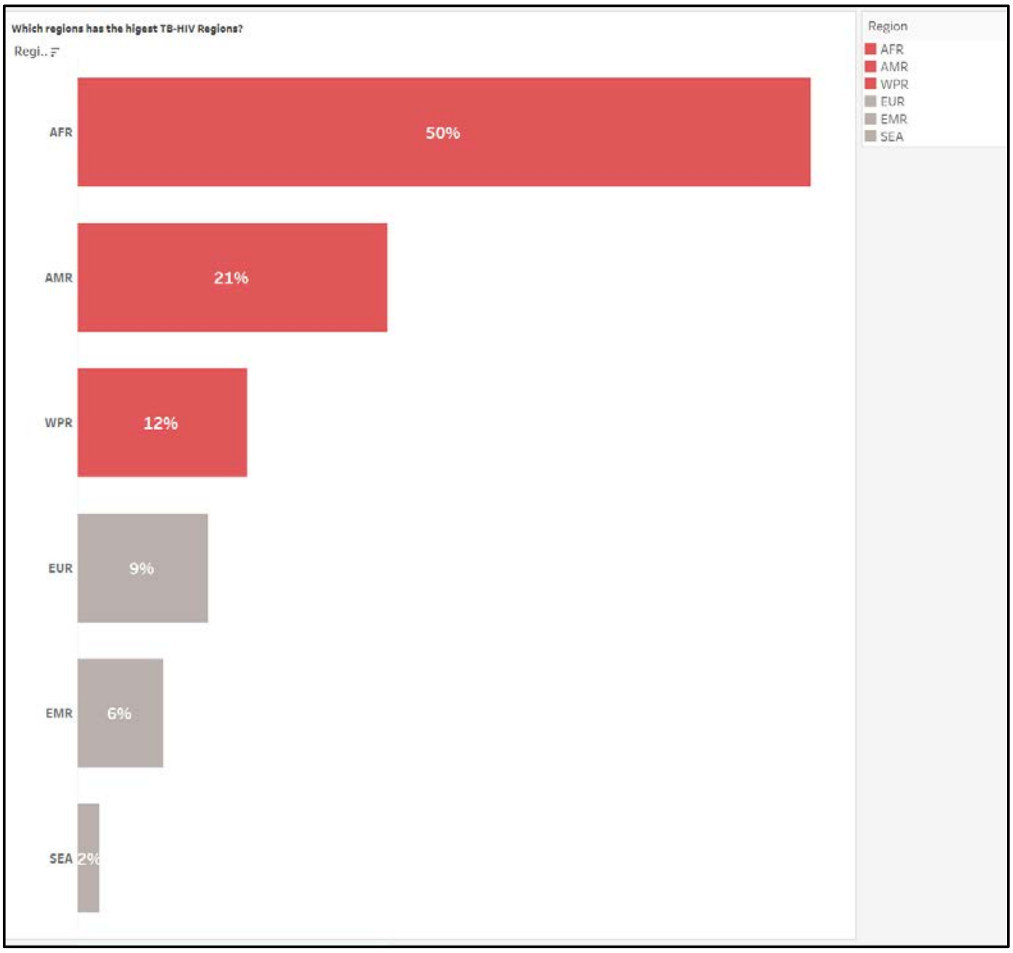


Figure 2: Bar plot: Highest Positive HIV across six regions

2) How likely are the most impacted regions to see changes in HIV rates over the next 5 Years?

Time series analysis suggests varying HIV trends across regions over the next five years. In Africa, where the highest infection rate peaked at 31.4% in 2003, a 23.89% decline is expected. The Americas, with a peak of 13.8% in 2009, are projected to decrease from 12.6% to 11.11% by 2018. The Western Pacific, where rates ranged from 7.9% to 8.2% (2002–2013), will see a slight drop to 8% by 2018. In South-East Asia, HIV rates, which rose from 3.22% (1998) to 4.9% (2004), are forecasted to decline from 4.4% (2013) to 4.2% by 2018.

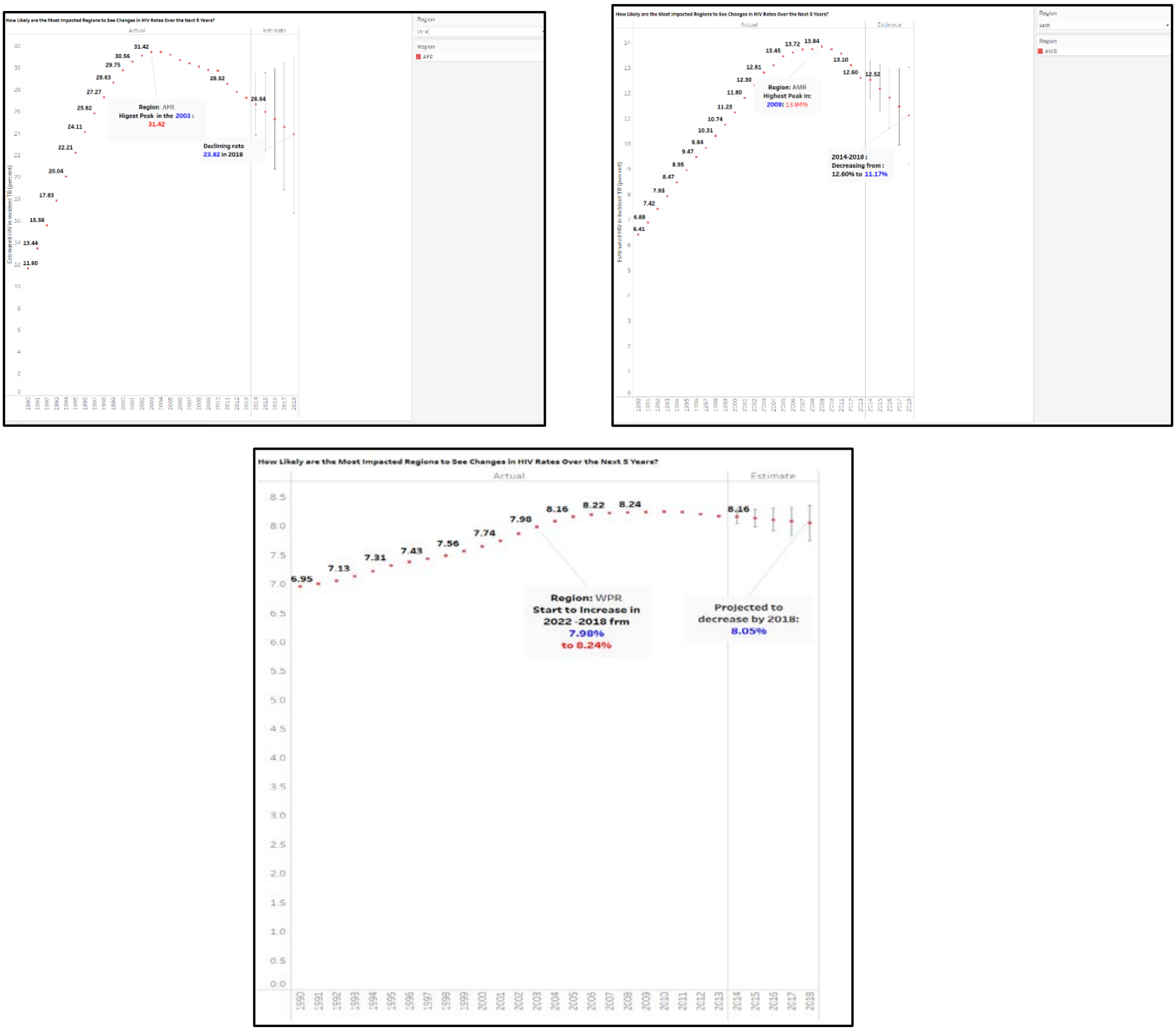


Figure 3: AMR, AFR and WPR 5 Year lookout

B. TB- Prevalence

Of the 340,701,776 HIV cases associated with TB, Southeast Asia (SEA) has the highest rate at 43%, with India, Myanmar, Thailand, and Indonesia contributing significantly. The Western Pacific Region (WPR) follows at 23%, with China and Cambodia showing notable prevalence. Africa (AFR) accounts for 18%, with sub-Saharan countries like South Africa and Nigeria affected. These figures highlight the need for targeted public health strategies in SEA, WPR, and AFR to improve HIV and TB screening, integrate treatments, and enhance healthcare access.

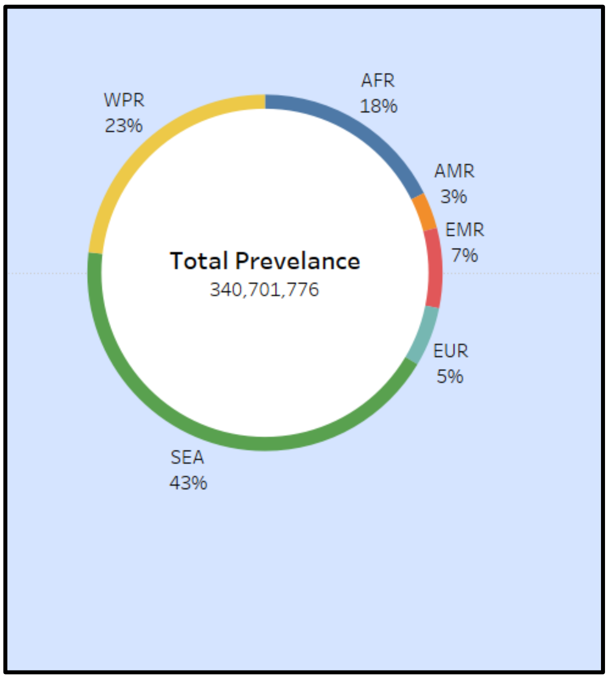


Figure 4: Donut chart: Total Prevalence across the regions

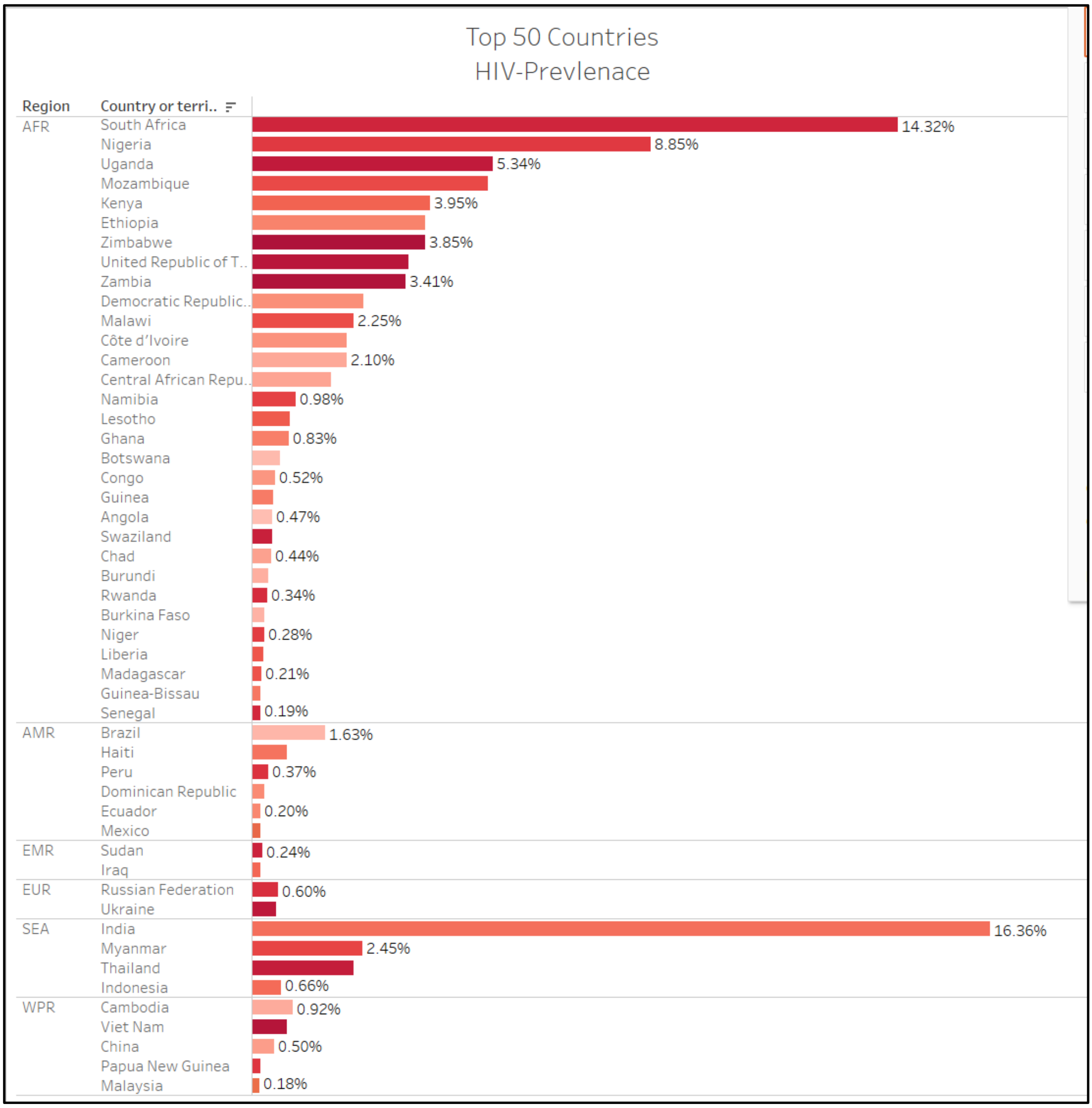


Figure 5: Bar plot: Top 50 HIV-prevalence countries & regions

1) Which region has the highest HIV-Prevalence Co-infections?

Of the total 340,701,776 prevalence cases, low-income regions in Africa (AFR) account for 68.82% of HIV cases, while Southeast Asia (SEA) represents 21.13%. In SEA, nearly half of individuals who are susceptible to infection and disease progression are living with HIV, emphasizing significant regional disparities in HIV-TB co-infection(Bastian, 2005).

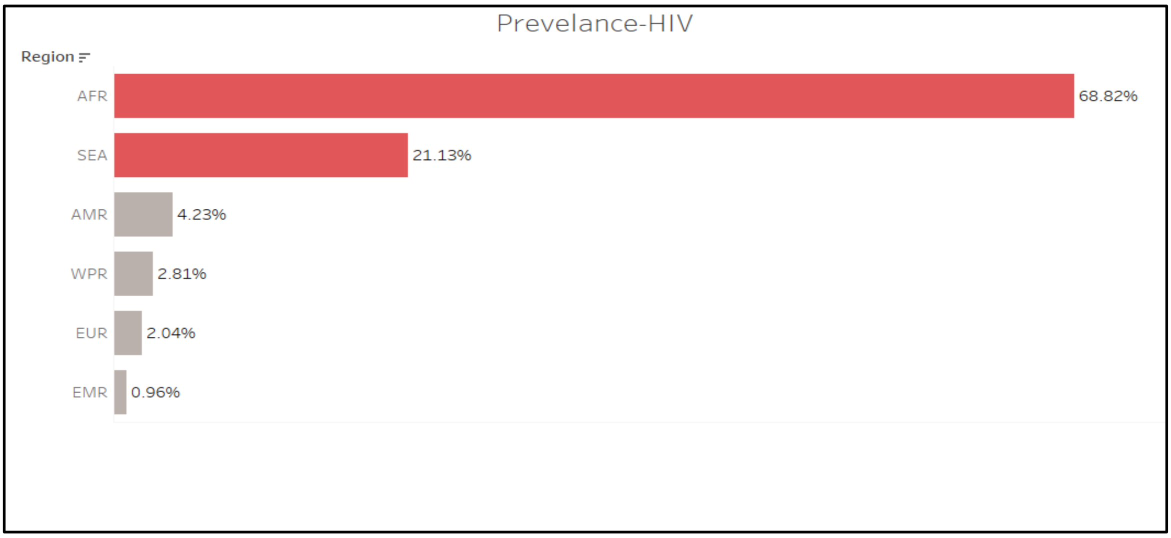


Figure 6: Bar-plot of HIV-Prevalence

2) Why AMR, WPR regions control HIV-infectious better than SEA & AFR?

(Sihombing et al., 2023) highlighted the significant of **AMR** (Antimicrobial Resistance could better control of HIV infections in the Americas (AMR) and Western Pacific Region (WPR) compared to Southeast Asia (SEA) and Africa (AFR) can be attributed to several key factors. While the total regional average HIV prevalence is 388.6, the lowest rates are found in AMR (9.7) and WPR (8.1), while SEA (208.1) and AFR (154.3) show much higher rates.

The primary reasons for these differences include:

1. **Antimicrobial Stewardship**: AMR and WPR benefit from better antimicrobial stewardship, with more effective regulation and use of antibiotics, which helps in controlling infections, including HIV-related co-infections.
2. **Access to Healthcare**: Countries in AMR and WPR generally have greater access to healthcare facilities, resources, and infrastructure, allowing for better prevention, early diagnosis, and treatment of HIV and related infections.
3. **Clinical Trial Capacity**: These regions have higher clinical trial capacities and better healthcare research infrastructures, which foster the development and implementation of more effective HIV treatment and prevention strategies.

In contrast, the **South-East Asia Region** is severely impacted by AMR due to factors such as rapid intensification of food production systems, loosely regulated access to antimicrobials, poor awareness of resistance issues, widespread irrational prescribing, and self-medication.

Furthermore, the availability of substandard or counterfeit drugs exacerbates the problem. Combined with a high prevalence of infectious diseases and weak healthcare systems, these factors drive the spread of AMR and complicate efforts to control HIV in SEA.

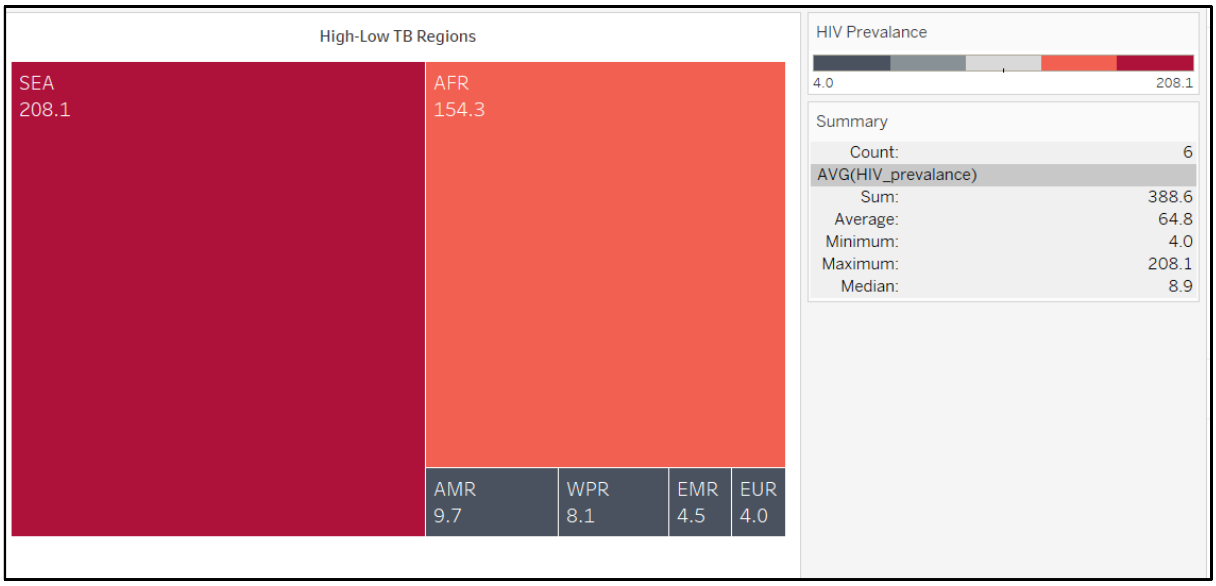


Figure 7: Heatmap: Average HIV-prevalence across six regions

3) HIV Prevalence Trends over the Next 5-years in High Burden Regions: AFR & SEA

Since 1996, TB-HIV co-infection prevalence has varied by region. In Southeast Asia, it peaked at 333.8 in 2004, then declined to 205.7 by 2013, with projections expecting a further drop to 110.4 in five years. In Africa, prevalence peaked at 198.3 in 2004, then decreased to 179.3 by 2013, with a further decline to 163 by 2018. These declines reflect the success of initiatives like the Harm Reduction Advocacy in Asia (HRAsia), which has improved prevention, early detection, and access to antiretroviral therapies, reducing transmission and enhancing treatment. (International, 2022), which has improved prevention, early detection, and access to antiretroviral therapies, reducing transmission and enhancing treatment.

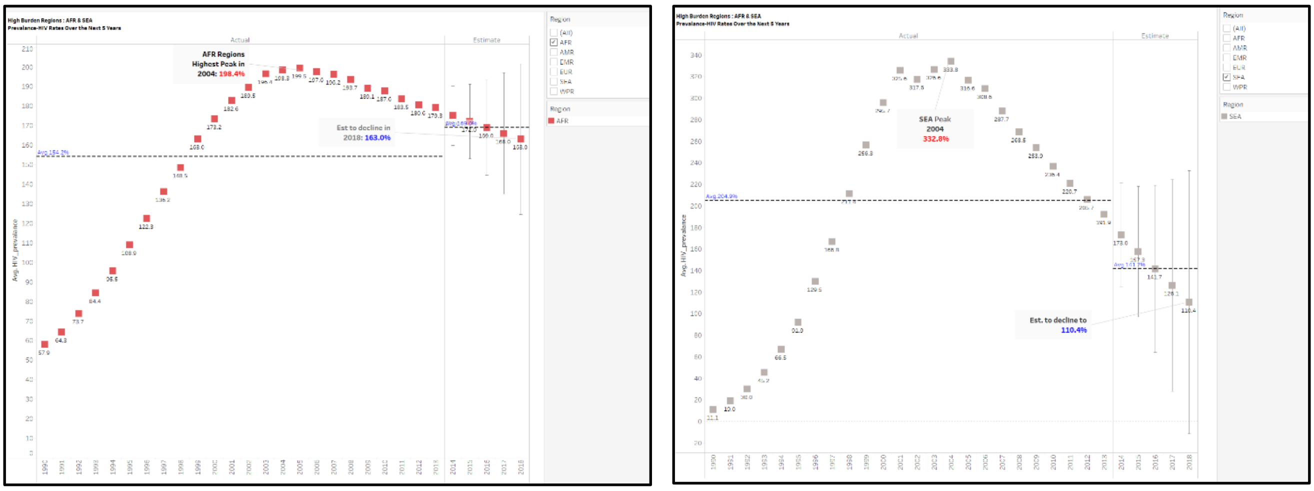


Figure 8: Line Plot AFR & SEA 5-years Trend

4) Improve the data collection strategies to reduce the risk of HIV-Prevalence

The method of data collection significantly influences HIV prevalence reports, impacting the accuracy and timeliness of identifying at-risk individuals. SEA reports the highest HIV prevalence at 56%.In the European region (EUR), where the National Tuberculosis Program (NTP) survey is least utilized, participant-only surveys are more common.

Data collection methods significantly impact HIV prevalence reports. In Southeast Asia (SEA), where healthcare access is limited, imputation methods inflate estimates and may miss hidden cases, delaying interventions. In Europe (EUR), participant-only surveys provide more accurate data due to direct HIV testing. In Africa (AFR), reliance on imputation also leads to underreporting and delayed detection. Improving data collection, with expanded testing and real-time reporting, is crucial for effective intervention in high-prevalence regions like SEA and AFR(Gilmour et al., 2023).

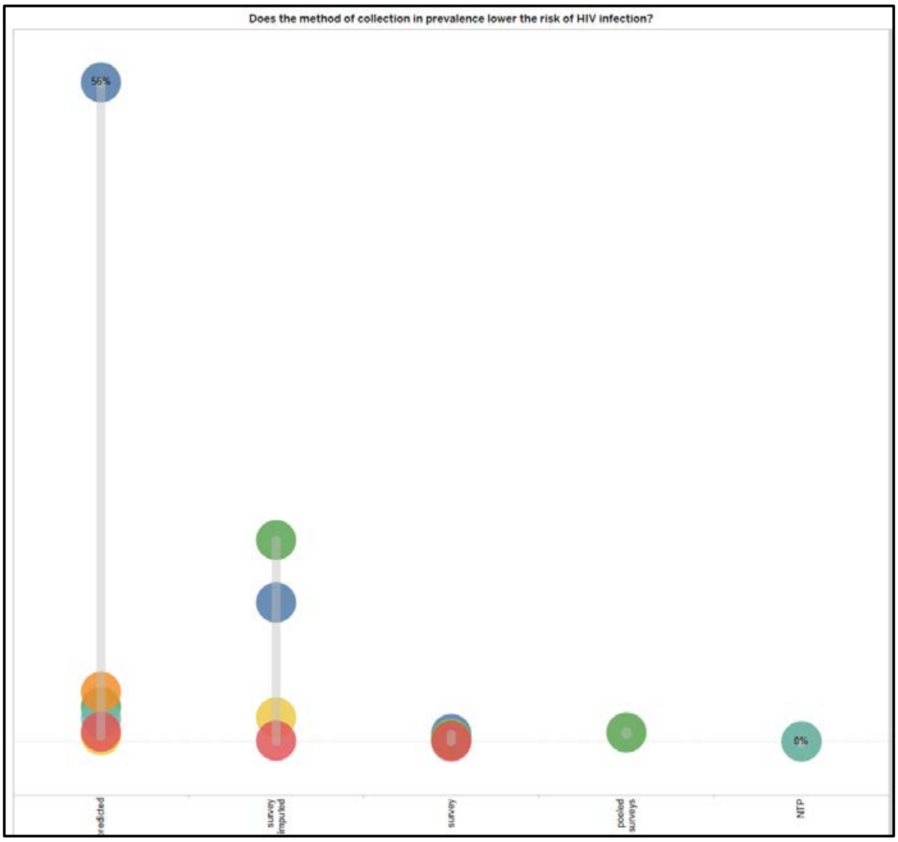


Figure 9: Dot plot: HIV-Prevalence survey method

C. TB-Incidence

Analyzing TB incidence provides critical advantages for public health planning by capturing new case rates. This approach enables meaningful comparisons between regions regardless of population size, reveals transmission patterns over time, guides resource allocation to high-burden areas, monitors intervention effectiveness, identifies co-infection relationships (particularly with HIV), and supports forecast modeling for long-term TB control strategies. By focusing on incidence, we gain a more accurate understanding of the disease burden and transmission dynamics, ultimately supporting evidence-based decision-making in global TB elimination efforts.

1) Countries with the Highest Incidence Rates

India has the highest number of incident cases at approximately 50 million, significantly higher than any other country. China follows with around 30-35 million cases. Indonesia, Nigeria, and Pakistan form the middle tier with roughly 10 million cases each, while South Africa, Bangladesh, Philippines, Ethiopia, and Myanmar have progressively fewer cases, ranging from about 8 million down to 4 million. Countries with very large populations like India and China naturally tend to have higher absolute case numbers.

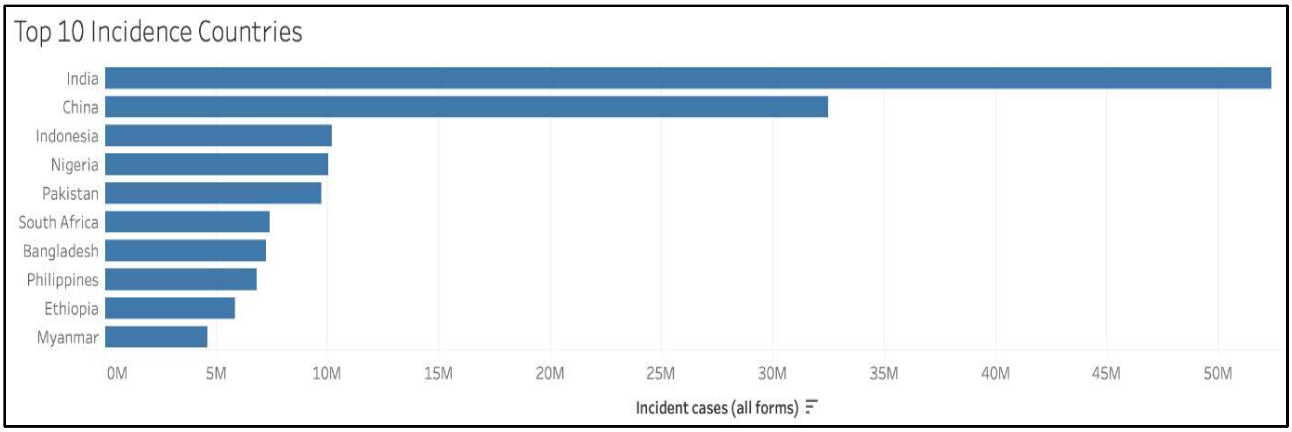


Figure 10: Bar Plot: Top 10 Incidence Countries

2) Is there a strong correlation between high TB incidence and HIV rates?

This scatter plot shows the relationship between TB incidence cases (all forms) per 100,000 population on the x-axis and HIV-positive incidence cases per 100,000 population on the y-axis, with data points color-coded by region. The graph reveals a strong correlation between TB and HIV incidence, particularly in the African region (AFR), which shows significantly higher rates of both diseases compared to other regions.

Several African countries exhibit extremely high dual burden, with some reaching up to 25,000 TB cases and 14,000 HIV-positive cases per 100,000 population. Other regions (AMR, EMR, EUR, SEA, WPR) cluster at much lower rates, typically below 5,000 cases for both diseases. This visualization highlights the disproportionate HIV-TB co-infection burden in Africa and suggests that HIV may be a significant driver of TB epidemics in high-prevalence settings.

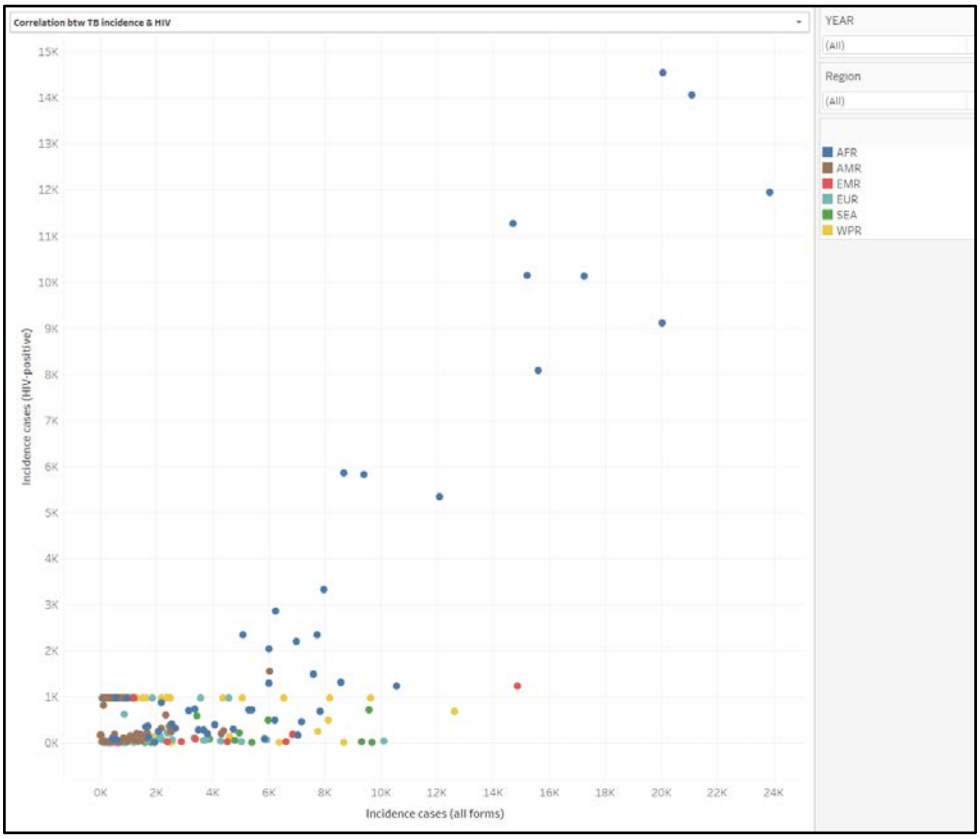


Figure 11: Scatterplot: Correlation between TB HIV Incidence across regions

3) Global TB Incidence Trends by Region: Per 100,000 Population

The graph shows TB incidence trends per 100,000 population across different regions from 1990 to 2018, including both actual data and future estimates. The African region (AFR) clearly bears the heaviest burden, with rates peaking around 16,000 cases per 100,000 in the early 2000s before declining to about 13,000 by 2012, with projections continuing downward. The Western Pacific region (WPR) shows the second highest incidence, starting at nearly 6,000 cases in 1990 and steadily declining to about 4,000 by 2012.

The European region (EUR) experienced an increase from 1990 to 2000, followed by a consistent decline. All other regions (AMR, EMR, SEA) maintained relatively stable and lower incidence rates between 1,000-3,000 cases per 100,000. Overall, the data shows encouraging downward trends across all regions after 2000, suggesting gradually improving TB control globally, though significant regional disparities persist.

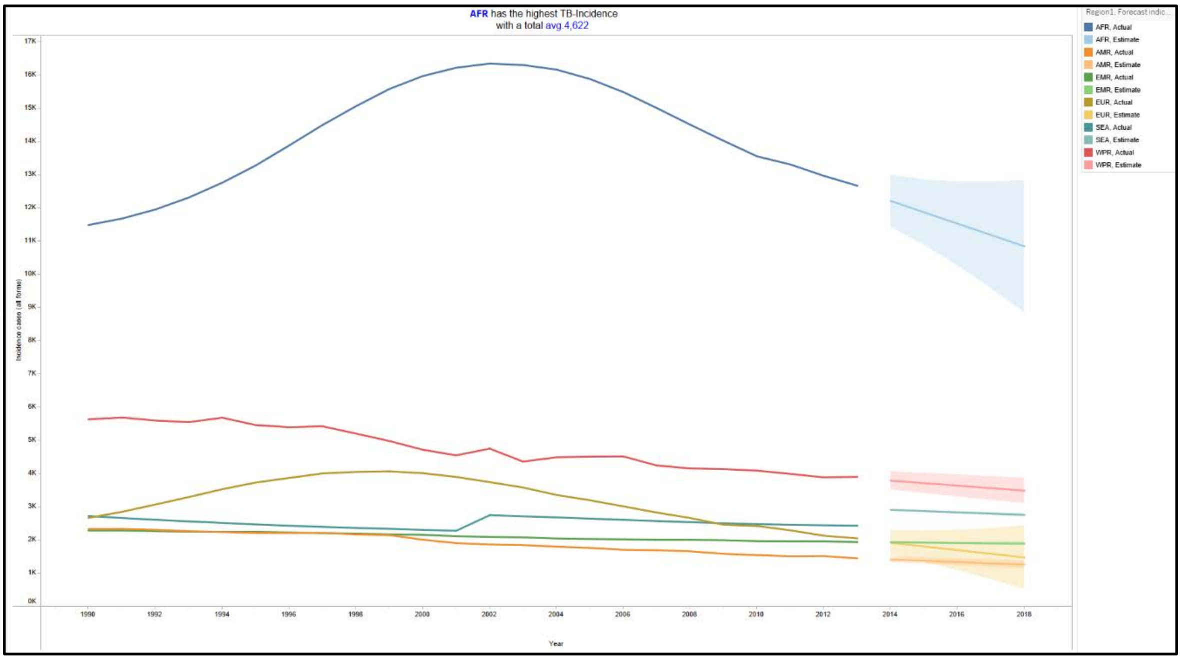


Figure 12: Line plot of TB-Incidence 5-year Trends across regions

D. TB-Mortality

TB mortality is highest in regions with limited healthcare access, poor diagnostics, and high HIV co-infection rates. Beyond health, it reduces workforce productivity, increases healthcare costs, and deepens poverty, particularly in low-income countries. The following analysis explores TB mortality, its correlation with HIV, and the broader implications of the TB-HIV epidemic.

1) Interplay between HIV and non-HIV

The Year-to-Date (YTD) mortality reported across the six regions stands at 52,611. Among these regions, the African region (AFR) has the highest non-HIV mortality, accounting for 92% of total mortality, with 54% of this attributable to HIV-related infections. In contrast, the Western Pacific Region (WPR) reports 22% of its mortality due to HIV, while the European Region (EUR) and Southeast Asia (SEA) report 11% and 10%, respectively. The Eastern Mediterranean Region (EMR) has the lowest HIV-related mortality, contributing only 1% of total mortality.

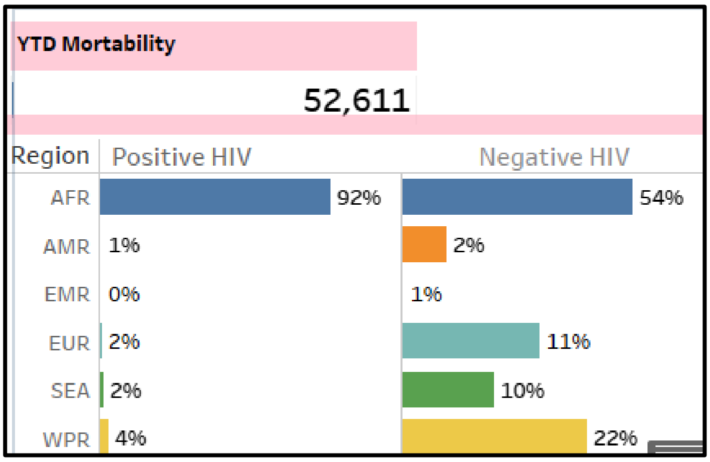


Figure 13: Bar plot of HIV and non-HIV Mortality

2)The dramatic rise and fall of TB-HIV Mortality across regions and nations

The trend in TB-HIV mortality has experienced dramatic fluctuations over the years, heavily influenced by factors such as the HIV/AIDS epidemic, healthcare interventions, and varying socioeconomic conditions. These changes underscore the complexity of managing the dual burden of tuberculosis (TB) and HIV in different regions of the world.

Global Overview

Between 1992 and 2001, mortality rates saw significant increases, peaking in 1998 at 3.19%. The growth slowed by 2001 with a slight rise of 0.26%. In 2002, there was a small decrease of -0.64%, followed by a rebound in 2003 (+0.87). From 2004 to 2014, rates generally declined, with a sharp drop in 2004 (-4.35) and a gradual decrease to -1.69 by 2014, reflecting a fluctuating mortality trend.

Southeast Asia (SEA)

In **India**, the TB-HIV mortality rate rose from **3.1 per 100,000** population in **1998** to a peak of **6.2 per 100,000** in **2004**. However, by **2013**, the mortality rate had decreased to **3.0 per 100,000**, reflecting improvements in healthcare access, particularly the widespread availability of **Antiretroviral Therapy (ART)**.

WPR

In contrast, **China** made significant strides in reducing its TB mortality rate, which decreased by approximately **80%** from **1990 to 2010**, dropping from **0.010** to **0.0017 per 100,000**. Between **2004 and 2014**, the number of new TB cases in China fell by **17%**, from **0.04** to **0.017 per 100,000**. These improvements were largely driven by strengthened TB control programs and an enhanced healthcare infrastructure.

Europe

In **Eastern Europe**, particularly after the dissolution of the Soviet Union(Field, 2004), TB mortality rates fluctuated significantly, with a notable increase in TB-related deaths following the rise of HIV. In **Russia**, the TB mortality rate rose from **0.04 per 100,000** in **1991** to **0.43 per 100,000** in **1999** and further increased to **1.5 per 100,000** by **2005**. However, by **2015**, the rate decreased to **0.98 per 100,000**, reflecting a complex interplay of healthcare challenges, HIV, and TB.

Africa

In Africa, the implementation of the Directly Observed Treatment Short-course (DOTS) strategy (Maher, 1999)played a significant role in improving treatment success rates. In Rwanda, for example, the treatment success rate increased from 11% in 2003 to 74% by 2006.

These positive outcomes were due to expanded DOTS coverage and enhanced diagnostic and treatment services. However, the dual burden of TB and HIV continued to pose significant challenges to healthcare systems across the continent.

Year ..	
1991	
1992	1.88%▲
1993	1.53%▲
1994	1.45%▲
1995	3.20%▲
1996	1.82%▲
1997	2.21%▲
1998	3.19%▲
1999	2.34%▲
2000	0.73%▲
2001	0.26%▲
2002	-0.64%▼
2003	0.87%▲
2004	-4.35%▼
2005	-3.38%▼
2006	-5.31%▼
2007	-5.74%▼
2008	-7.21%▼
2009	-7.36%▼
2010	-5.63%▼
2011	-4.69%▼
2012	-4.71%▼
2013	-4.09%▼
2014	-1.69%▼

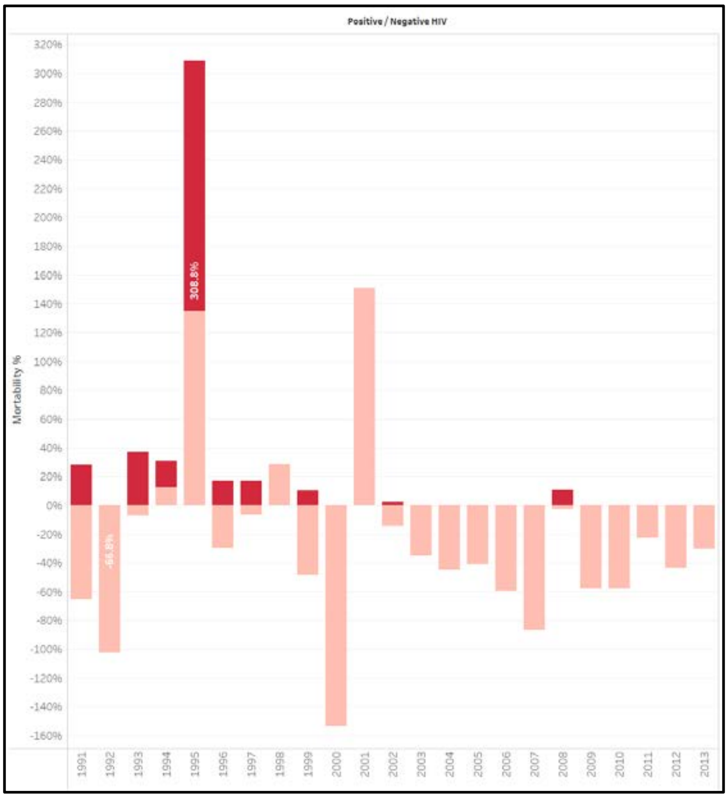


Figure 14: Total Mortality Up-down trends

Figure 15: Waterfall plot: HIV and Non-HIV

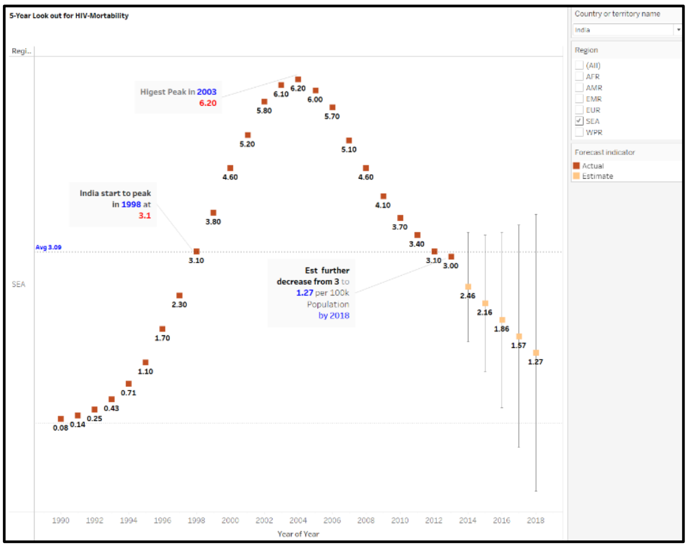


Figure 16: Line graph: SEA: India

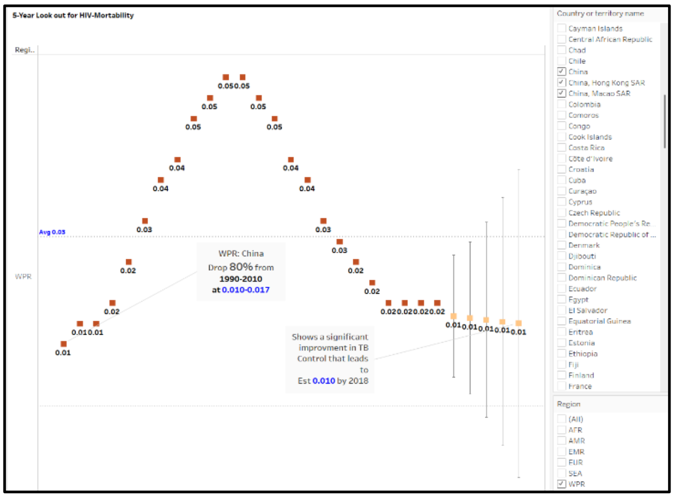


Figure 17: Line graph: WPR: China

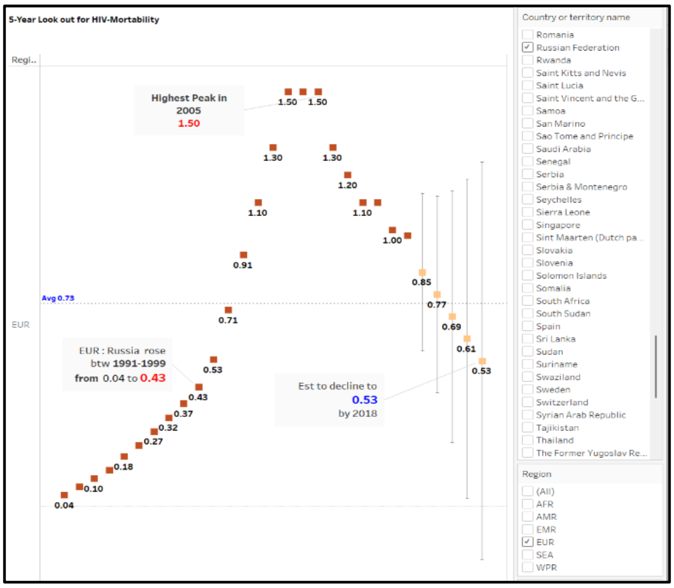


Figure 18: Line graphs: EMR regions: Russia

3) What Interventions in the AMR Region Have Contributed to Lower HIV Rates, and How Can High-Burden Regions Adapt These Strategies to Reduce HIV Risk?

As shown by the heatmap, the **AMR** region demonstrates the lowest HIV mortality rate (0.38), compared to higher rates seen in **AFR** (34.66), **SEA** (4.28), and **WPR** (3.31).

The Americas (AMR) region has implemented a comprehensive approach to HIV treatment and prevention. This includes ensuring access to antiretroviral therapy (ART), promoting prevention and education, advancing research and development, and providing social support programs. These efforts have been crucial in reducing HIV mortality and improving the quality of life for people living with HIV.

In contrast, regions like Southeast Asia (SEA) and the Western Pacific (WPR) have progressively adopted various strategies to control HIV. For example, Thailand has successfully implemented subsidized condom distribution, needle exchange programs, and safe sex campaigns. Similarly, Vietnam has significantly expanded access to ART, with international aid and support from organizations like the Global Fund helping to provide life-saving treatment.

In the Western Pacific (WPR) region, Australia stands out as a success story in controlling HIV. With low transmission rates and high treatment coverage, Australia's early intervention strategies and well-resourced healthcare system have made a significant impact. Its "test and treat" policy, along with the PrEP program and comprehensive HIV testing and prevention policies, has led to a marked reduction in new HIV cases, especially among MSM communities. The country's approach has resulted in extremely low HIV-related mortality.

On the other hand, Africa (AFR) continues to face significant challenges in controlling HIV. However, efforts to combat the epidemic remain ongoing. Initiatives, such as global health aid, are crucial in supporting low-resource countries to strengthen their HIV prevention and treatment programs and reduce HIV-related mortality rates.

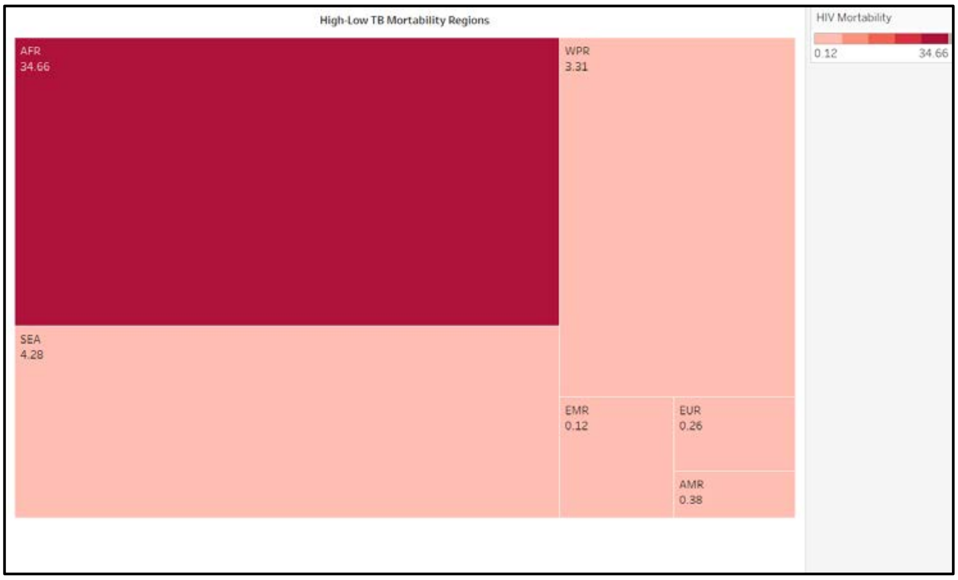


Figure19: Heatmap of High-Low TB Burden Regions

4) Enhancing TB Mortality Data Collection Capacity

The African region (AFR) has the highest HIV-related mortality among the six WHO regions, with a median mortality of 39 and a peak of 1,128 in 2002. Unlike the Americas (AMR), which primarily rely on vital registration (VR) and VR-imputed data for accurate mortality tracking, AFR depends largely on indirect collection methods, leading to gaps in data accuracy.

The challenges in capturing HIV-related mortality in AFR stem from limited VR systems, making alternative methods like verbal autopsies necessary. Verbal autopsy, which involves structured interviews with caregivers or witnesses to determine the cause of death, provides useful insights but lacks the precision of medical certification (Fox et al., 2010). In contrast, regions with robust VR systems, such as AMR, have more reliable mortality data.

This discrepancy underscores the need for strengthened regional efforts to improve data accuracy and timeliness. Expanding comprehensive VR systems, improving real-time reporting, and integrating advanced surveillance techniques can enhance monitoring, support targeted interventions, and refine strategies for reducing TB-HIV mortality in high-burden regions.

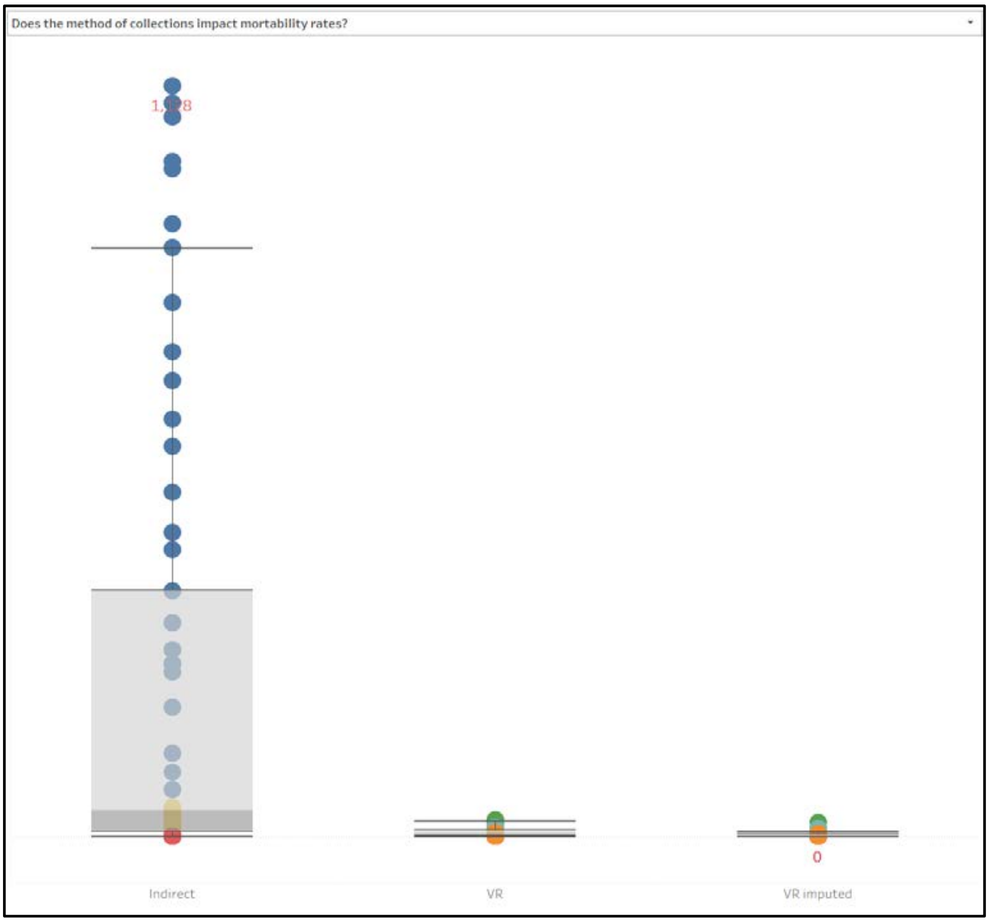


Figure 20: Boxplot of Various TB Mortality Methods

5) Highly Endemic regions TB-Mortality 5 years lookout

HIV-Related Mortality Trends in the African (AFR) Region: Key Factors and Progress

Countries in the African (AFR) region, particularly those with high case fatality rates (CFR), have historically experienced the highest HIV-related mortality globally. Mortality rates in the region rose significantly, reaching 373 in 1995 and peaking at 437 in 1998. However, over the years, this trend has seen a steady decline, with the mortality rate gradually decreasing to 61 by the early 2000s.

Recent Trends and Decline

Between 2013 and 2018, this decline continued, reaching 3.55 in 2018. This represents a remarkable reduction in HIV-related deaths and highlights the significant progress made in addressing the HIV epidemic within the region. The sustained decrease in mortality underscores the effectiveness of public health interventions and the significant lives saved as a result of these efforts(WHO, 2024).

Key Contributing Factors

1.**Enhanced Prevention Efforts**: AFR has implemented successful HIV prevention programs, including public health campaigns, condom distribution, and safe sex education, reducing new infections and HIV-related deaths.

2.**Expanded Access to ART**: Increased access to antiretroviral therapy (ART) has improved life expectancy and reduced HIV-related mortality by halting AIDS progression and lowering viral loads.

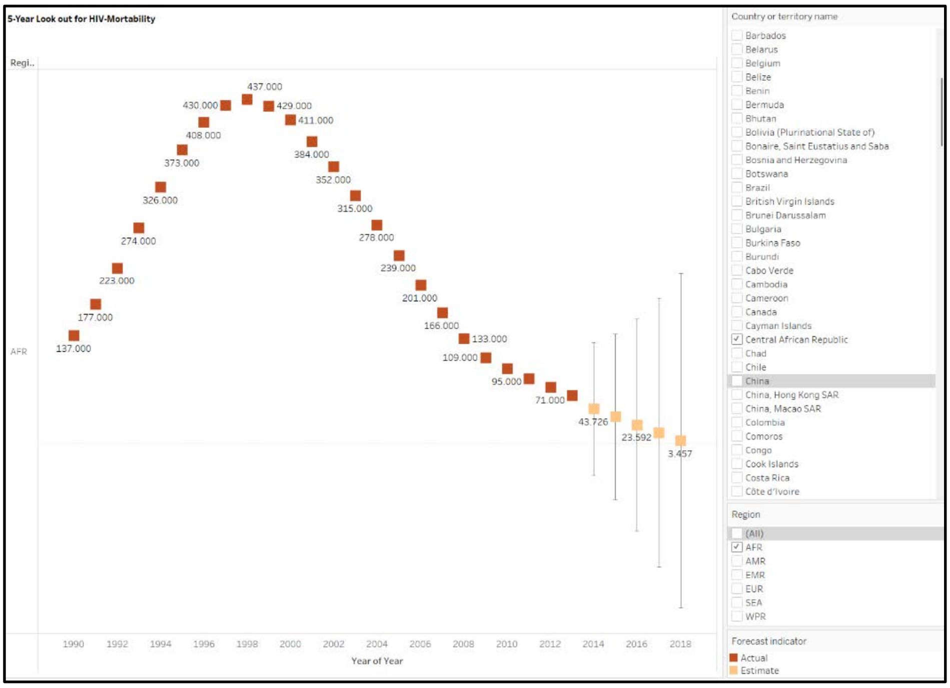


Figure 21: Line graph: 5-year predictive of TB mortality rate with HIV

HIV-Related Mortality Trends in the Southeast Asia (SEA) Region: Key Initiatives and Outcomes

The Southeast Asia (SEA) region has experienced significant fluctuations in HIV-related mortality over the past few decades. HIV-related mortality reached a peak of 5.069 in 2001, before undergoing a substantial decline to 0.702 by 2018. This positive trend is largely the result of several key initiatives and interventions aimed at controlling the HIV epidemic and improving health outcomes in the region.

1.Enhanced HIV Prevention Programs: SEA's comprehensive HIV prevention programs, targeting high-risk groups and promoting safe sex, condom use, harm reduction, and early testing, have significantly reduced HIV-related mortality.

2. Strengthened Healthcare Infrastructure: Collaborations with organizations like USAID and the Global Fund have improved SEA's healthcare infrastructure, leading to better diagnostics, treatment programs, and expanded services, particularly in underserved areas.

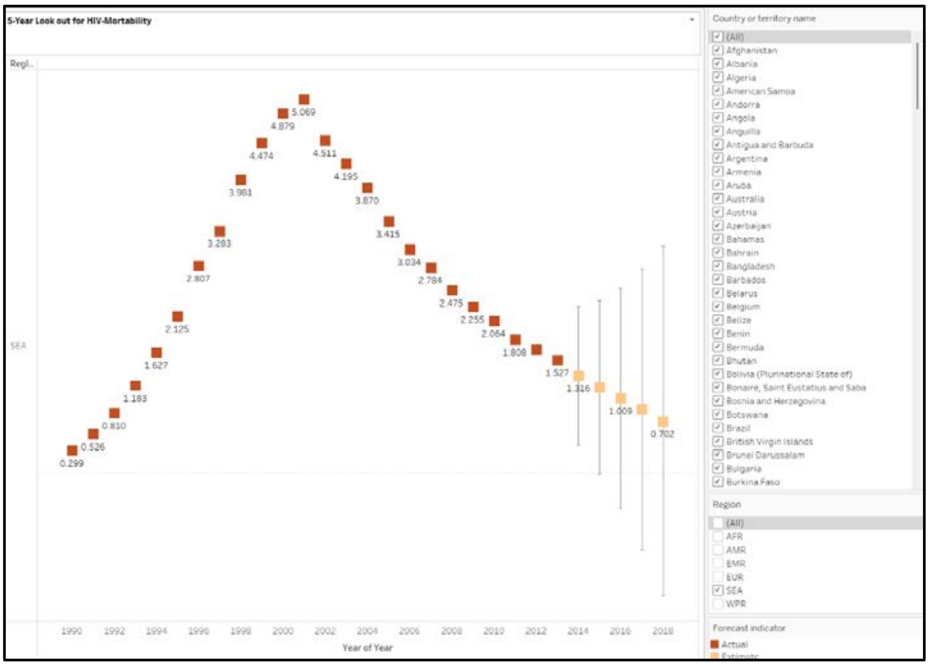


Figure 22: Line plot: SEA Regions

HIV-Related Mortality Trends in the Western Pacific Region (WPR): Strategies and Outcomes

The Western Pacific Region (WPR) has witnessed a significant decline in HIV-related mortality in recent years. The region experienced a peak of 1.324 in HIV-related mortality in 2002, which has since decreased to 0.350 according to the most recent five-year forecast. This positive trend is primarily attributed to the implementation of various key strategies aimed at reducing HIV-related mortality. These strategies have been crucial in addressing the challenges of HIV and its co-infection with tuberculosis (TB), improving diagnosis and treatment, and enhancing public health interventions across the region.

1. Tuberculosis (TB) Care Programs

One of the most significant factors contributing to the reduction in HIV-related mortality is the integration of TB care with HIV treatment. Co-infection with HIV and TB is a leading cause of death in the region, and addressing this through joint care programs has been highly effective. Countries such as **Vietnam** and **Cambodia** have successfully implemented harm reduction programs alongside public awareness campaigns. These initiatives have significantly reduced mortality rates linked to both TB and HIV. Additionally, **China** expanded HIV testing and integrated TB-HIV care, leading to improved treatment outcomes.

2. Improved Testing and Diagnosis

The enhancement of HIV testing initiatives has played a pivotal role in early diagnosis and timely treatment, which has been vital in reducing mortality rates. In countries like **Australia** and **New Zealand**, comprehensive HIV care has been prioritized. This includes expanded access to antiretroviral therapy (ART) and prevention programs, ensuring that individuals diagnosed with HIV receive immediate and effective treatment, thus improving their health outcomes.

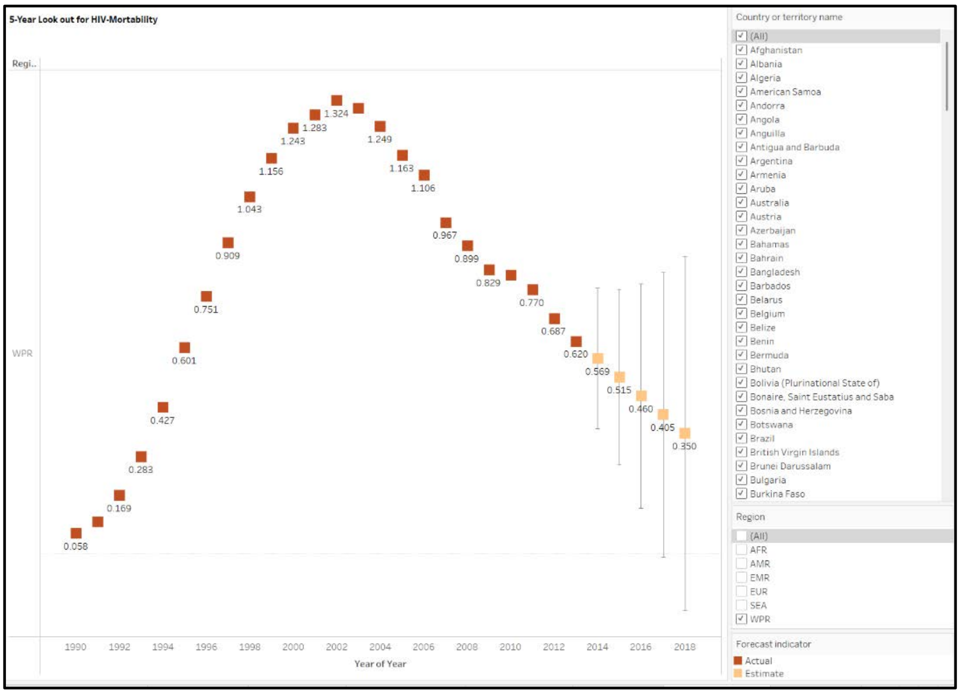


Figure 23: Line Plot: WPR Regions

6) Statistical Significance of the Linear Model for TB Mortality in HIV-Positive Individuals

A linear regression model was applied to predict the log of the median estimated mortality of TB cases who are HIV-positive per 100,000 population, based on the median estimated incidence of TB cases who are HIV-positive per 100,000 population. The model aimed to understand the relationship between TB incidence and mortality in HIV-positive individuals across three rural and less undeveloped countries: India, Bangladesh, and Nigeria.

Model Summary

log (Median Estimated Mortality) =−0.163397+(0.0119308×Median Estimated Incidence)

The model fit was evaluated using the R-squared value, which indicated that approximately 40% of the variance in TB mortality can be explained by the variance in TB incidence (R^2 = 0.40097). The mean squared error (MSE) was calculated to be 4.39891, indicating the average squared deviation between observed and predicted mortality rates. The p-value for the regression model was found to be less than 0.0001 ($p < 0.0001$), which is highly significant. This indicates that the model's relationship between TB incidence and mortality is statistically significant.

Interpretation of Coefficients

- The intercept of the model was -0.163397, which represents the predicted log mortality when the median TB incidence is zero.
- The slope coefficient for the median incidence of TB per 100,000 population was 0.0119308, suggesting that for every unit increase in TB incidence, the log of TB mortality in HIV-positive individuals increases by approximately 0.0119.

Nigeria	Corr = 0.9856 Predicted Mortality for Nigeria =−0.163397+(0.0119308×75) = 0.731413 Predicted Median Mortality=e−0.16220392≈**2.078**
India	Corr =0.9727 Predicted Mortality for India = -0.163397+(0.0119308*10) =-0.044089 Predicted Median Mortality= e−0.044089 =**0.9569**
Bangladesh	Corr=0.9859 Predicted Mortality for Bangladesh =−0.163397+(0.0119308×0.1) =−0.16220392 Predicted Median Mortality=e−0.16220392≈**0.850**

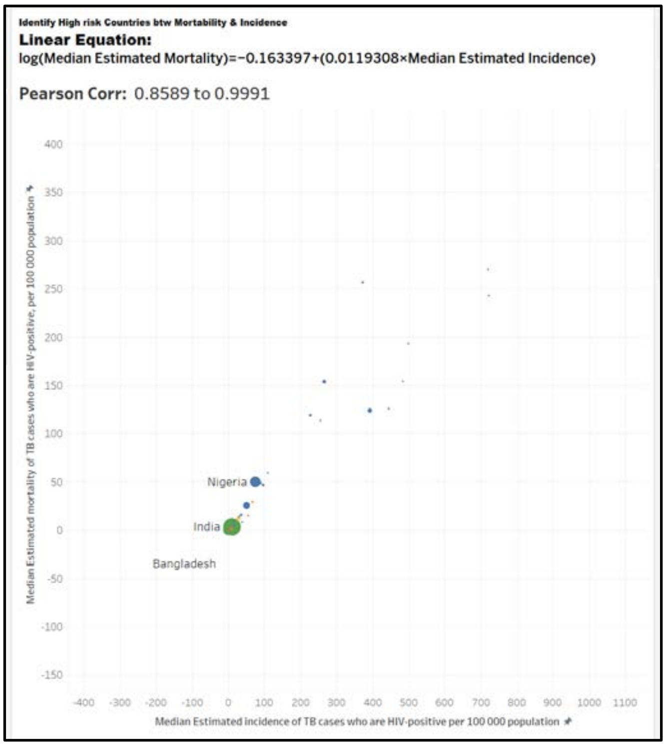


Figure 24: scatter plot: Pearson correlation between three countries

The statistical significance of the regression model ($p < 0.0001$) indicates that there is a strong, statistically significant relationship between the incidence of TB and the mortality rate in HIV-positive individuals across the three countries studied. Despite the model's high significance, discrepancies between the predicted and observed values suggest that factors beyond TB incidence may influence mortality rates, such as healthcare access, regional differences, and the broader HIV burden.

These findings suggest that countries like Nigeria, India and Bangladesh, and should continue to prioritize public health interventions to address TB mortality, especially in rural areas where healthcare access is limited. However, further refinement of the model, accounting for additional factors such as healthcare infrastructure and HIV-related interventions, may provide a more accurate prediction.

E. TB-Death

TB disease can cause significant health risks, especially for individuals with HIV or other conditions that weaken the immune system. Without proper treatment, it can lead to severe complications or even fatalities. Bases on WHO's TB burden data from 1990 to 2013, the following analysis of death case from TB incidence has been conducted. From this analysis, we find that

1) Top ten Countries and region which has the highest number of TB-related death cases with HIV and without HIV and
2) Declining TB related death-cases with HIV and without HIV co-infection since 2013.
3) Higher fatality rates in TB cases Co-infected with HIV than without HIV.

1) Top ten countries which has the lowest or highest number of death cases from TB incidence

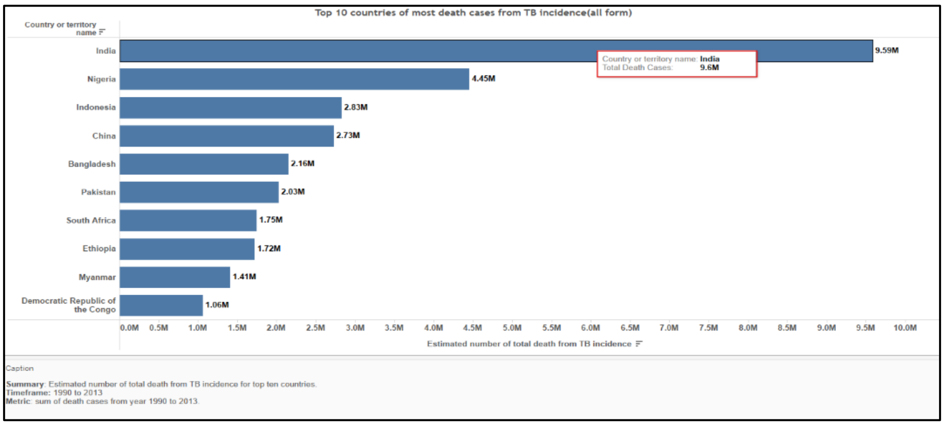


Figure 25: Bar Plot: Top ten countries of most death cases from TB incidence (all form)

This bar chart clearly presents the top ten countries with the highest number of TB-related deaths (all forms) in descending order. India ranks first, with 9.59 million deaths over the 13-year period from 1990 to 2013, followed by Nigeria, which also recorded a substantial number of TB-related fatalities. Indonesia, China, and Bangladesh also experienced a significant number of TB-related death cases. Among the top ten countries, the Democratic Republic of the Congo had the lowest number of fatalities, with an estimated 1.06 million deaths. This highlights the disproportionate TB burden in high-population countries, particularly in Southeast Asia and Africa.

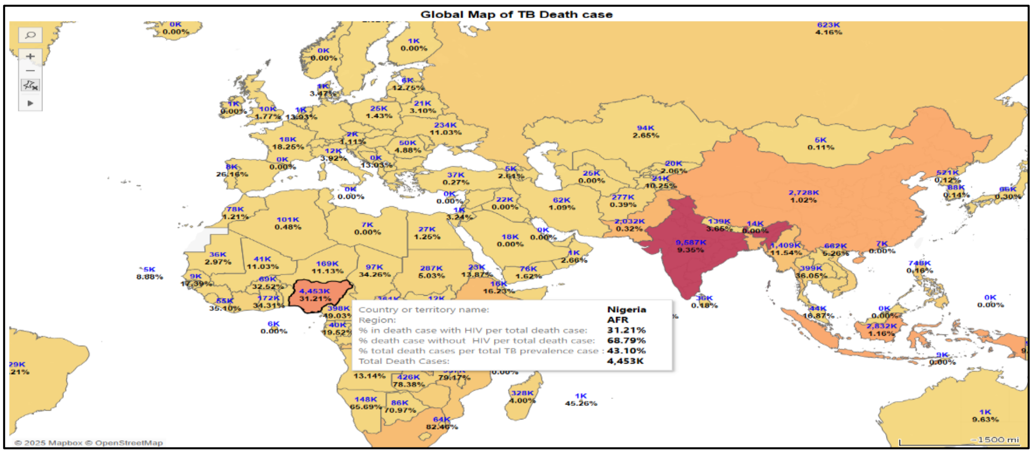
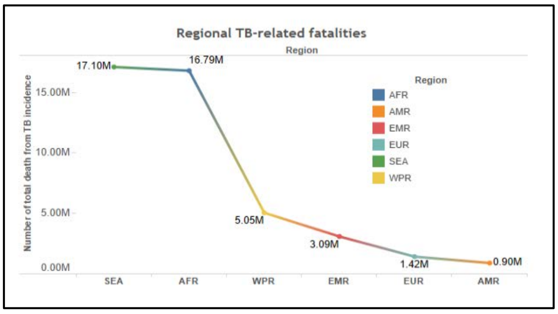


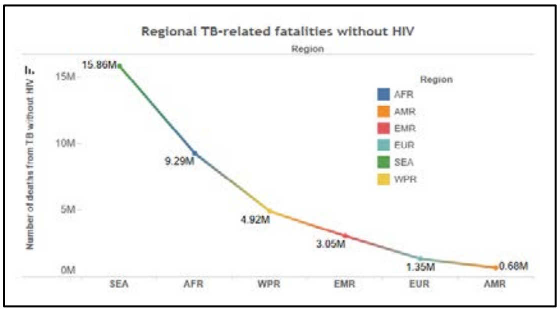
Figure 26: Globally number of TB-related death case

From the colour distributed global map, it is evident that Southeast Asia and Africa experienced higher TB-related fatalities compared to other regions from year 1990 to 2013.

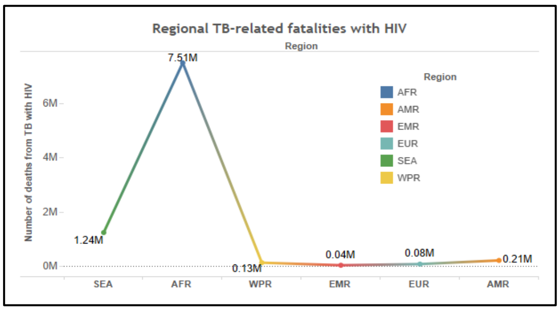
Regional TB-related fatalities



The line chart shows total number of TB-related fatalities across regions over 13 years. Southeast Asia had the highest deaths (17.10M), followed by Africa (16.79M). The Western Pacific (5.05M) and Eastern Mediterranean (3.09M) had moderate numbers, while Europe (1.42M) and Americas (0.90M) recorded the lowest.



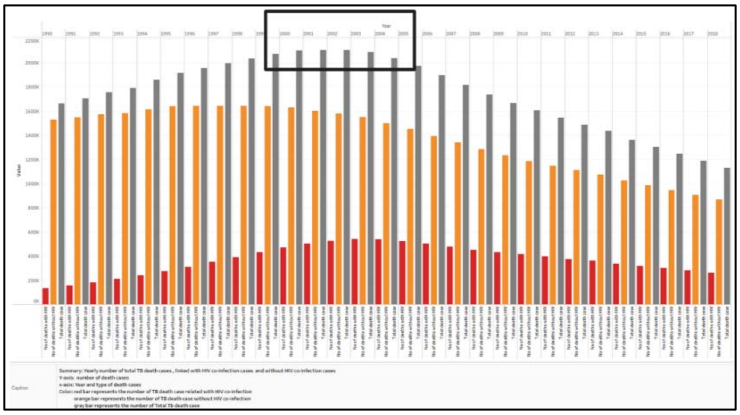
This line graph illustrates the SEA region had the highest TB-related death without HIV co-infection among the six regions. Africa ranked second in highest number of TB-related deaths, while Americas had the lowest number, with 0.68 million deaths



In contrast, the line plot represents the regional TB death cases with HIV. It indicates that African region had the highest number of deaths from 1990 to 2013. This could be due to a lack of awareness regarding the causes, prevention, and treatment of both TB and HIV.

Figure 27: Line plots: Regional TB related death case

2) Declining TB-related death case with and without HIV co-infection since 2013



SUM(Number of deaths from TB without HIV)	
Sum:	35.14M
Average:	1.46M
Minimum:	1.07M
Maximum:	1.64M
Median:	1.55M
SUM(Number of deaths from TB with HIV)	
Sum:	9.21M
Average:	0.38M
Minimum:	0.14M
Maximum:	0.54M
Median:	0.41M
AGG(Estimated number of total death from TB ...	
Sum:	44.35M
Average:	1.85M
Minimum:	1.43M
Maximum:	2.11M
Median:	1.88M

Figure 28: Bar plot: TB Death HIV and non-HIV Trends and summary of death case

Yearly number of total TB death cases, TB death cases with and without HIV, and summary table

The bar chart represents yearly TB-related deaths over a 13-year period, categorized into total deaths from TB, deaths associated with TB and HIV, and deaths from TB without HIV. Both the total number of deaths case and fatalities linked to HIV showed a steady increase from 1990 to the early 2000s before beginning to decline.

The summary table presents TB-related fatalities over a 13-year period, totaling 44.35 million deaths. The average annual TB-related death count is 1.85 million. Among these, 9.21 million deaths were associated with HIV, accounting for above 20% of the total TB-related fatalities, with an average of 0.38 million per year. Meanwhile, TB deaths unrelated to HIV totaled 35.14 million, making up nearly 80% of all TB-related deaths, with an average of 1.46 million per year.

The peak in total death cases, including those with HIV co-infection, occurred between 2000 and 2003, followed by a steady decline until 2013. This trend suggests that the death rate decrement might be due to the improvements in treatment, healthcare interventions, public health measures, and increased awareness of tuberculosis cause and HIV prevention methods.

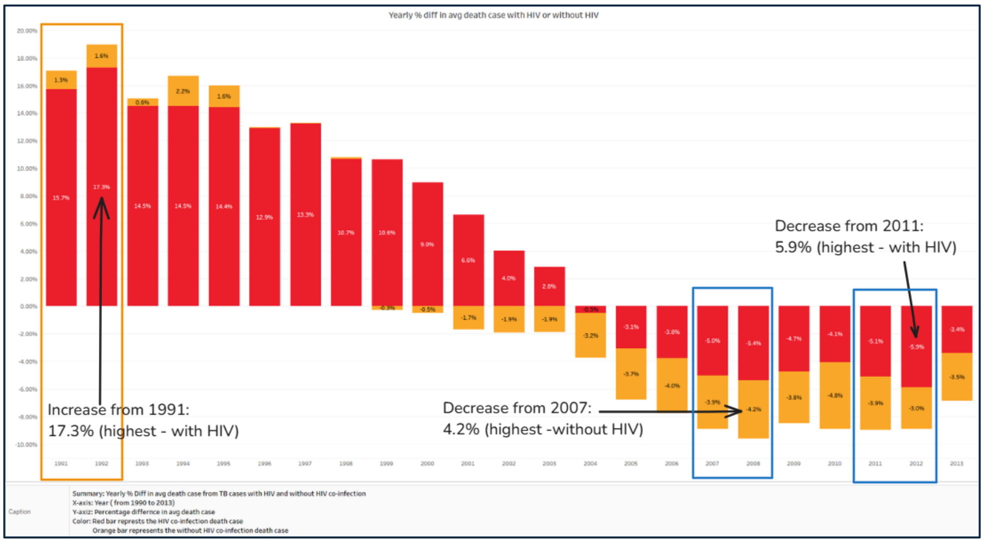


Figure 29: Bar plot: Yearly percentage difference in average TB death case with HIV and non-HIV

The bar chart illustrates the yearly percentage difference in average death cases between HIV co-infection and without HIV co-infection. Prior to year 2000, it is indicating that the percentage difference gradually increased, reaching its peak increasement in 1992 at 17.3% the highest recorded rise compared to 1991. In the early 2000s, the trend shifted as the death rates for both groups began to decline steadily. The most significant decline rate in HIV co-infection cases occurred in 2012 which is 5.9% compared to year 2011. Meanwhile, the steepest drop in non-HIV co-infected cases was observed in 2008 (-4.2%) compared to 2007.

These patterns support those medical advancements, interventions and increased awareness and education about both diseases introduced in the 2000s. It might have significantly contributed to reducing the fatalities rate.

3) Higher Fatality rates in TB cases Co-infected with HIV than without HIV

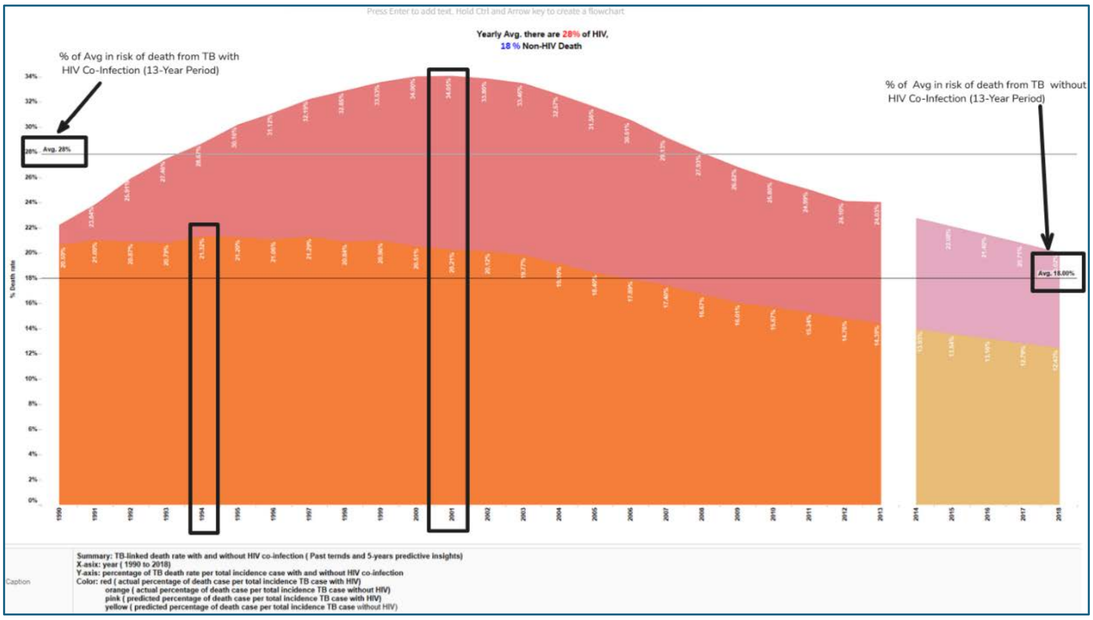


Figure 30: Area under the curve: TB-Death past and Future 5-years Trends

Risk of death from TB linked cases with and without HIV: Past Trends and 5-year Predictive Insights

The area graph illustrates the yearly percentage of the risk of death from TB cases, distinguishing between those with and without HIV co-infection. The data reveals a significant decline in death rates for both groups after the early 2000s.The highest recorded risk of death among TB cases with HIV co-infection occurred in 2001, peaking at 31.05%. Following this peak, the rate steadily declined.

In contrast, TB cases without HIV co-infection experienced their highest death rate in 1994, reaching 21.32%. Over a 13-year period, TB cases with HIV co-infection exhibited a 10% higher fatality rate on average compared to cases without HIV co-infection.

How likely to be the risk of death from TB linked with HIV and without HIV co infection cases from 2014 to 2018?

The chart also provides five-year predictive insights, forecasting a decline in the risk of death for both TB cases with and without HIV co-infection. From 2014 to 2018, the risk of death for TB cases with HIV co-infection is expected to decrease by 2%, while for those without HIV co-infection, a 1.5% decline is projected.

This graph highlights that TB cases co-infected with HIV have a consistently higher fatality rate than those without HIV. A possible explanation is that HIV weakens the immune system, reducing the body's ability to fight TB. The combination of complex treatment regimens and accelerated disease progression might contribute to the higher mortality rates observed in co-infected patients.

F. Correlation Analysis

Correlation is a statistical measure that describes the relationship between two variables. It tells us whether and how strongly two variables move together. The correlation coefficient is r (ranges between **-1 and +1)**

Types Of Correlation:

1. **Positive Correlation** – When one variable increases, the other also increases. Example: Higher education levels lead to higher salaries. (**r = +1** → Perfect positive correlation)

2. **Negative Correlation** – When one variable increases, the other decreases. Example: As exercise increases, body fat percentage decreases. (**r = -1** → Perfect negative correlation)

3. **No Correlation** – No relationship between the two variables. Example: Shoe size and intelligence. (**r = 0** → No correlation)

Significance of R-square and P value in correlation:

- **R-squared (R^2):** Measures the strength of correlation; higher values indicate a stronger relationship.

1. **P-value:** Assesses statistical significance; a low p-value (< 0.05) suggests the correlation is unlikely due to chance.

Key Findings:

1) TB INCIDENCE VS HIV Co Infection Rate

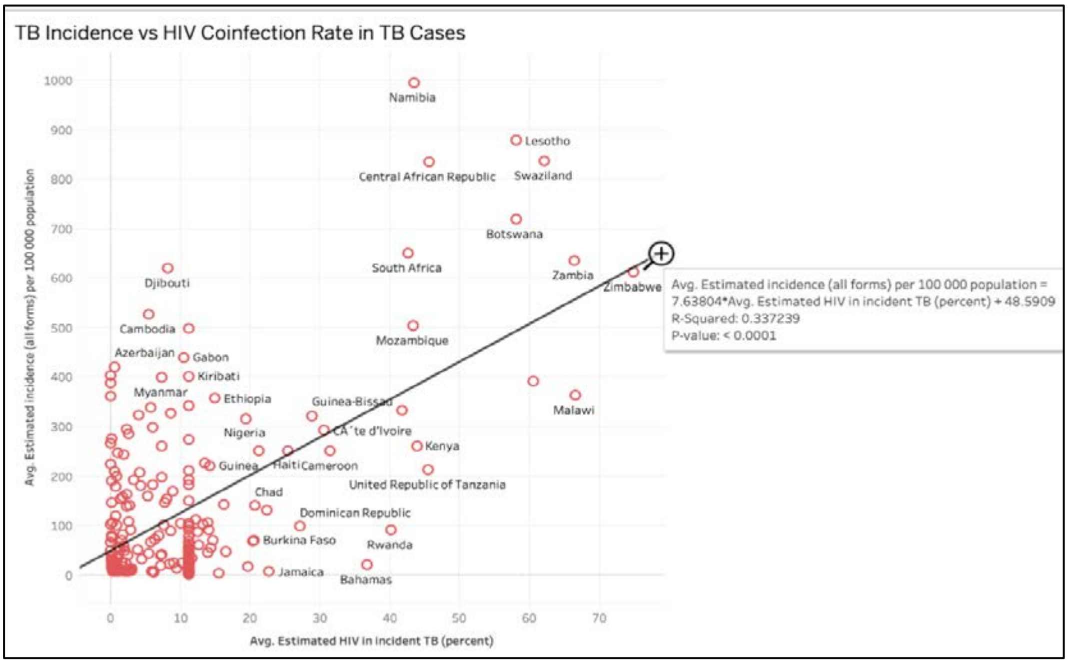


Figure 31: Scatter plot: the correlation between TB incidence and HIV coinfection

Tuberculosis (TB) remains a major public health concern, especially in regions with high HIV prevalence. This analysis explores the relationship between TB incidence and the rate of HIV coinfection in TB cases across different countries.

The scatter plot illustrates the link between TB incidence (per 100,000 population) and the percentage of TB cases involving HIV. Each red circle represents a country, showing how these two variables interact.

Variables in the Graph:

- **X-axis (Independent Variable):** Avg. Estimated HIV in Incident TB Cases (%)
- **Y-axis (Dependent Variable)**: Avg. Estimated incidence of TB (all forms) per 100,000 population
- **Data Points**: Represent different countries

A regression trendline has been added to understand the relationship between these two factors. The equation for this trendline is:

TB Incidence=7.63804× (HIV Coinfection Rate) +48.5909

This means:

- For every 1% increase in HIV coinfection rate, the TB incidence rate increases by about **7.64 cases per 100,000 population**.

Positive Correlation:

- There is a visible upward trend, indicating that as the percentage of HIV-positive TB cases increases, the overall incidence of TB rate also rises per 100,000 population
- This makes sense because HIV weakens the immune system, making individuals more susceptible to TB infections.

Strength of the Relationship (Correlation):

R-Squared (0.337): This indicates that about **33.7% of the variation in TB incidence can be explained by HIV coinfection rates**. The remaining 66.3% is influenced by other factors not included in the model.

While this suggests a moderate correlation, other factors also influence TB incidence. Overall, the strength of the correlation is moderate.

P-Value (<0.0001): The very low p-value confirms that this correlation is statistically significant, this means we can confidently state that the relationship observed is not due to random chance.

Notable observations:

Countries with high HIV coinfection rates, such as **Zimbabwe, Zambia, and South Africa**, also report higher TB incidence rates, emphasizing the need for integrated TB-HIV healthcare strategies. Countries, like **Jamaica and the Bahamas**, show lower TB incidence despite varying HIV coinfection rates, suggesting that other factors—such as healthcare infrastructure and socio-economic conditions—also play a critical role.

Conclusion:

This analysis highlights the strong positive correlation between HIV coinfection and TB incidence. While HIV plays a significant role in increasing TB cases, other factors such as healthcare access, vaccination programs, and socio-economic conditions also influence TB spread. Stakeholders shall consider these insights to develop the effective targeted interventions that address both TB and HIV as part of a comprehensive public health strategy.

2) TB Prevalence vs HIV Coinfection Rate in TB Cases

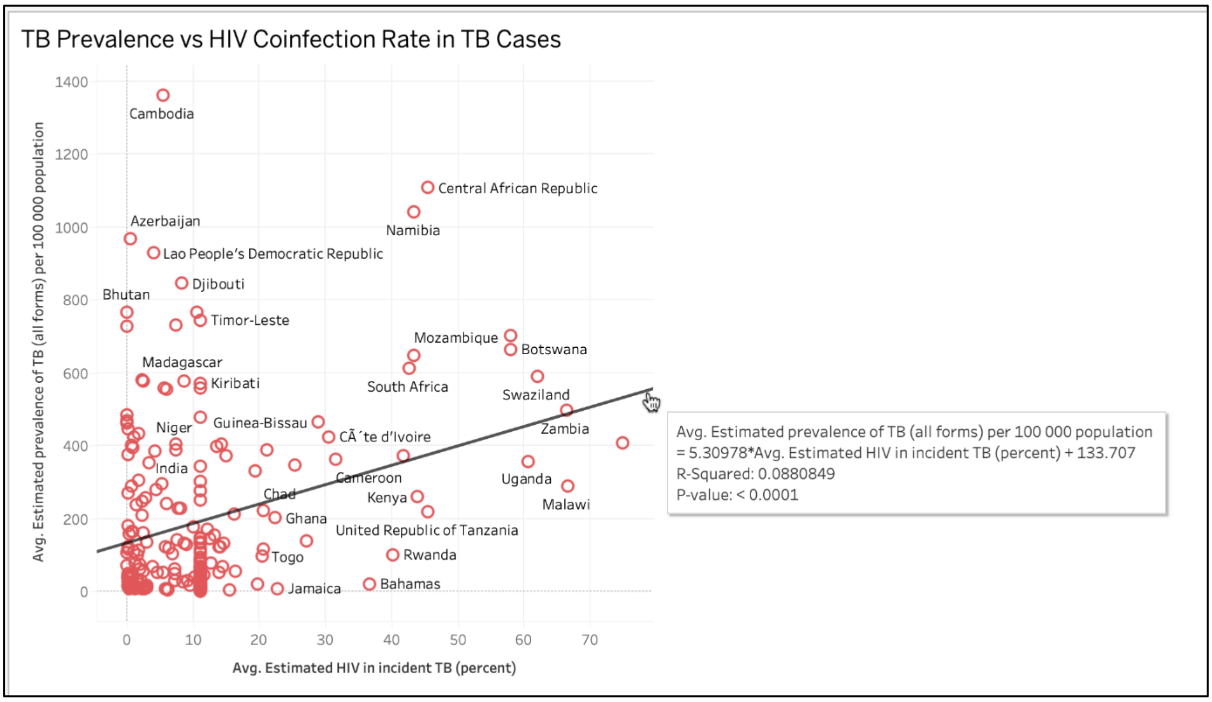


Figure 32: Scatter plot: Correlation between prevalence of TB (all form) and incident TB with HIV confection.

Tuberculosis (TB) and HIV are closely linked diseases, with HIV-positive individuals being more vulnerable to TB infections. This visualization explores whether a higher **HIV coinfection rate** is associated with an increase in **TB prevalence** across different countries.

Variables in the Graph:

- X-axis (Independent Variable): Avg. Estimated HIV in Incident TB Cases (%)
- Y-axis (Dependent Variable): Avg. Estimated Prevalence of TB (all forms) per 100,000 population
- Data Points: Represent different countries

Key Findings from the Trendline:

A regression trendline has been added to understand the relationship between these two factors. The equation for this trendline is:

TB Prevalence=5.31× (HIV Coinfection Rate) +133.71\text {TB Prevalence} = 5.31 \times (\text {HIV Coinfection Rate}) + 133.71TB Prevalence=5.31× (HIV Coinfection Rate) +133.71

Meaning that for every 1% increase in HIV coinfection, it is expected 5.31 more TB cases per 100,000 people. Even if no TB cases had HIV, TB prevalence would still be around 133.71 per 100,000 people, suggesting other factors at play.

Positive Correlation:

The trendline slopes upward, meaning that as the percentage of HIV coinfection in TB cases increases, the prevalence of TB also rises. This suggests that countries with higher HIV coinfection rates tend to experience more TB cases.

Strength of Correlation:

The R-squared value is 0.088, meaning only 8.8% of TB prevalence can be explained by HIV coinfection rates alone. Which is quite low. This tells us that while there is a connection between HIV coinfection and TB prevalence or it's a contributing factor, it is not a strong predictor or the biggest driver of TB cases.

Other factors, such as access to healthcare, living conditions, and TB control efforts, likely play a bigger role in determining TB prevalence. The p-value is less than 0.0001, indicating that the relationship is statistically significant—so it's unlikely to be due to chance.

Notable Observations:

Countries like Cambodia, Namibia, and Botswana have high TB prevalence even with moderate HIV rates, suggesting other local factors may be influencing TB cases.

Countries like Bhutan and Azerbaijan have relatively low TB rates, despite some level of HIV coinfection, possibly due to better healthcare systems or strong TB control measures.

Final Thoughts:

While the data shows a positive relationship between HIV and TB, it's clear that HIV coinfection alone does not fully explain the variations in TB prevalence. To get a more complete picture, we need to consider other influences, such as public health interventions, socioeconomic factors, and regional healthcare infrastructure which can help governments and healthcare organizations design better strategies to combat TB worldwide.

3) TB Mortality vs HIV Coinfection Rate in TB Cases

This analysis explores the relationship between HIV coinfection in TB cases and the mortality rate of TB among HIV-positive individuals. Each data point represents a country.

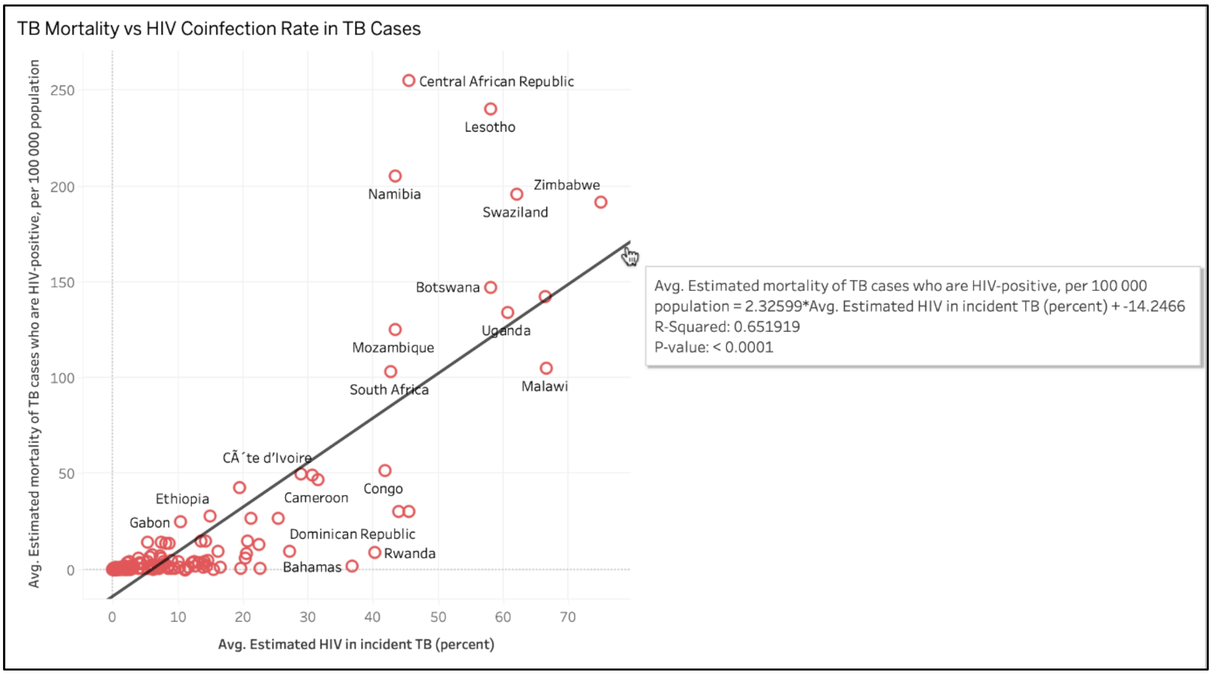


Figure 33: Scatter plot: Correlation between mortality of TB case and TB incident with impacted HIV cases

Variables in the Graph:

- X-axis → The percentage of TB cases that are also HIV-positive.
- Y-axis → The estimated mortality rate of TB cases among HIV-positive individuals (per 100,000 population).
- Data points: Represent different Countries

Key Findings:

A regression trendline has been added to understand the relationship between these two factors. The equation for this trendline is:

Regression Equation: TB Mortality Rate=2.33× (HIV Coinfection Rate) −14.25TB\Mortality\ Rate = 2.33 \times (HIV\ Coinfection\ Rate) - 14.25TB Mortality Rate=2.33×(HIV Coinfection Rate)−14.25

This means that for every 1% increase in HIV coinfection, TB mortality increases by approximately 2.33 deaths per 100,000 population.

Positive Correlation:

The trendline slopes upward and shows a strong positive correlation between HIV coinfection and TB mortality, meaning that as the percentage of HIV coinfection in TB cases increases, the mortality of TB also rises. This suggests that countries with higher HIV coinfection rates tend to experience more TB cases.

Strength of Correlation (R-Squared Value):

$R^2 = 0.65$ → This means 65% of the variation in TB mortality can be explained by HIV coinfection rates. While this indicates a strong correlation, it also suggests that other factors—such as healthcare access, treatment availability, and socioeconomic conditions—influence TB mortality.

Statistical Significance (P-Value):

P-value < 0.0001 → This confirms that the correlation is statistically significant and unlikely to be due to chance.

Country-Specific Observations:

Countries with high HIV coinfection rates and high TB mortality include Lesotho, Central African Republic, Zimbabwe, and Swaziland. Countries with lower HIV coinfection rates and lower TB mortality include Gabon, Ethiopia, and Jamaica.

Conclusion:

The analysis highlights HIV coinfection as a major factor driving TB mortality. Countries with higher HIV prevalence in TB cases tend to experience significantly higher TB-related deaths.

However, despite the strong correlation, HIV coinfection is not the only factor at play. Other elements—such as healthcare quality, TB treatment programs, and economic conditions—must also be considered when addressing TB mortality.

VII. Report Secondary Findings

This section looks in to how the prevalence and mortality of TB is closely tied with socio-economic and developmental factors of the countries listed in the dataset. The primary dataset is analyzed in conjunction with secondary set of data about key indicators such as Gross Domestic Product (GDP) per capita and the Human Development Index (HDI). By analyzing the relationships between TB prevalence and mortality and its relationship with GDP and HDI, through various visualizations, we aim to gain insights into how economic development, human well-being, and healthcare systems influence TB prevalence, mortality, and detection rates.

The insight we try to gain from this study is broken down in to below listed key objectives and its respective visualization.

- **Assessing GDP per Capita and TB Prevalence:** Determine if economic growth directly reduces TB cases using a scatter plot.
- **HDI and TB Mortality Analysis:** Evaluate whether improvements in human development lower TB-related deaths using a line chart.
- **TB Case Detection and GDP Relationship:** Examine if wealthier countries have better healthcare systems for diagnosing TB cases using a dual-axis chart.
- **Combined Impact of HDI and GDP on TB Mortality:** Use a heatmap to understand if social and economic growth contribute to lower death rates.
- **TB Incidence in Different HDI Categories:** Compare TB Incidence rates among Low, Medium, and High HDI countries using a box plot.

1) GDP per Capita vs. TB Prevalence

This scatter plot explores the relationship between a country's GDP per capita economic status and its TB prevalence rate (cases per 100,000 population). It helps visualize whether wealthier countries experience lower TB prevalence rates.

The visualization points out that countries with low GDP per capita tend to have higher TB prevalence rates, often exceeding 500 cases per 100,000 (E.g.: - Botswana, Gabon). Additionally, wealthier nations of the world exhibit significantly lower TB prevalence, often below 50 cases per 100,000 (E.g.: - Germany, New Zealand). However, some middle-income countries still experience moderate TB prevalence, indicating that GDP alone is not the sole factor influencing TB rates (E.g.: - Russian Federation, Romania).

This analysis shows the need of governments and international organizations to prioritize TB prevention programs in lower-income countries. Increasing healthcare funding, improving sanitation, and promoting vaccinations in low-GDP countries can help reduce TB prevalence (World Health Organization, 2023).

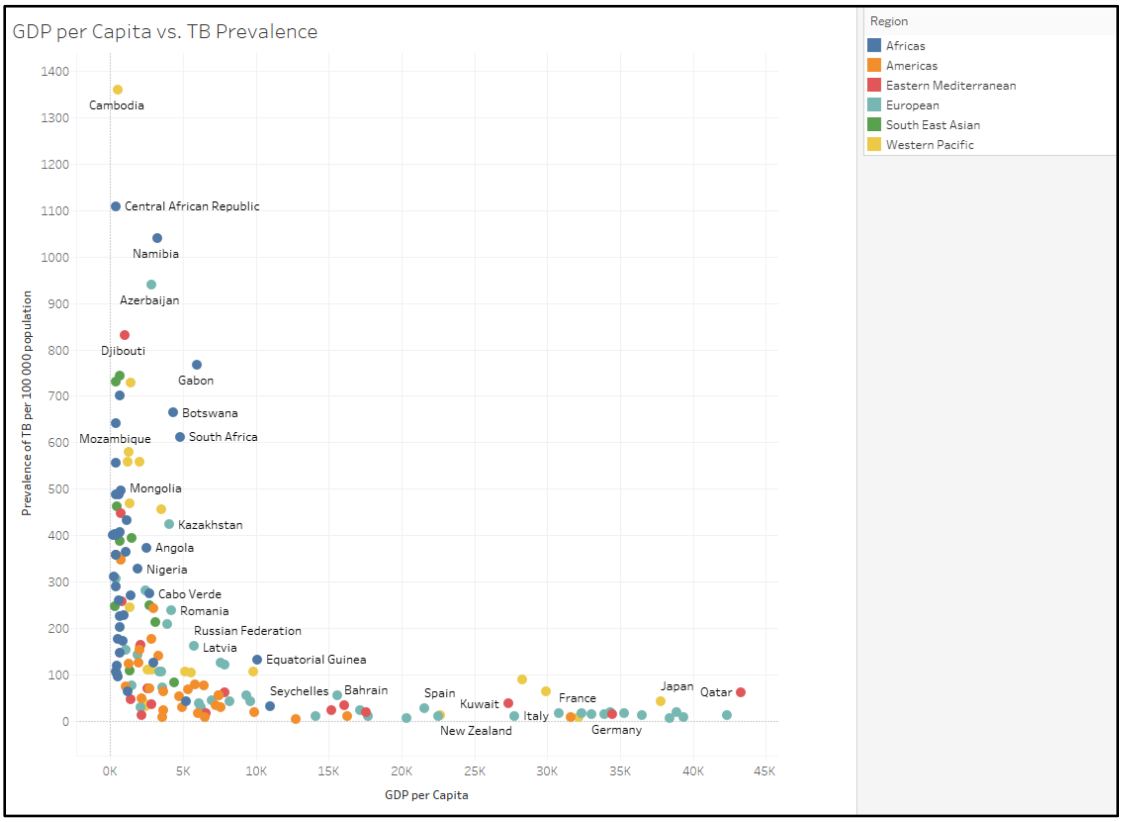


Figure 34: Scatterplot - GDP per Capita vs. TB Prevalence

2) Human Development Index (HDI) vs. TB Mortality Rate

HDI is an amalgamated index score of three key indicators a country's citizens, indicators are lifespan, educational attainment and adjusted real income (Blanchflower et al, 2005). The line chart visualizes the relationship between Human Development Index (HDI) and TB mortality rate over time, assessing how human development affects TB-related deaths. Countries with higher HDI (above 0.75) tend to have lower TB mortality rates, often below 5 deaths per 100,000. Countries with low HDI (below 0.55) see higher TB mortality rates, sometimes exceeding 100 deaths per 100,000. Over time, as countries improve their HDI, TB mortality rates decline.

The visualization show, over the years, how investing in education, healthcare access, and economic growth lowers TB mortality rates. Governments should ensure universal healthcare and support programs that improve nutrition and sanitation in low-HDI regions (United Nations Development Program, 2022).

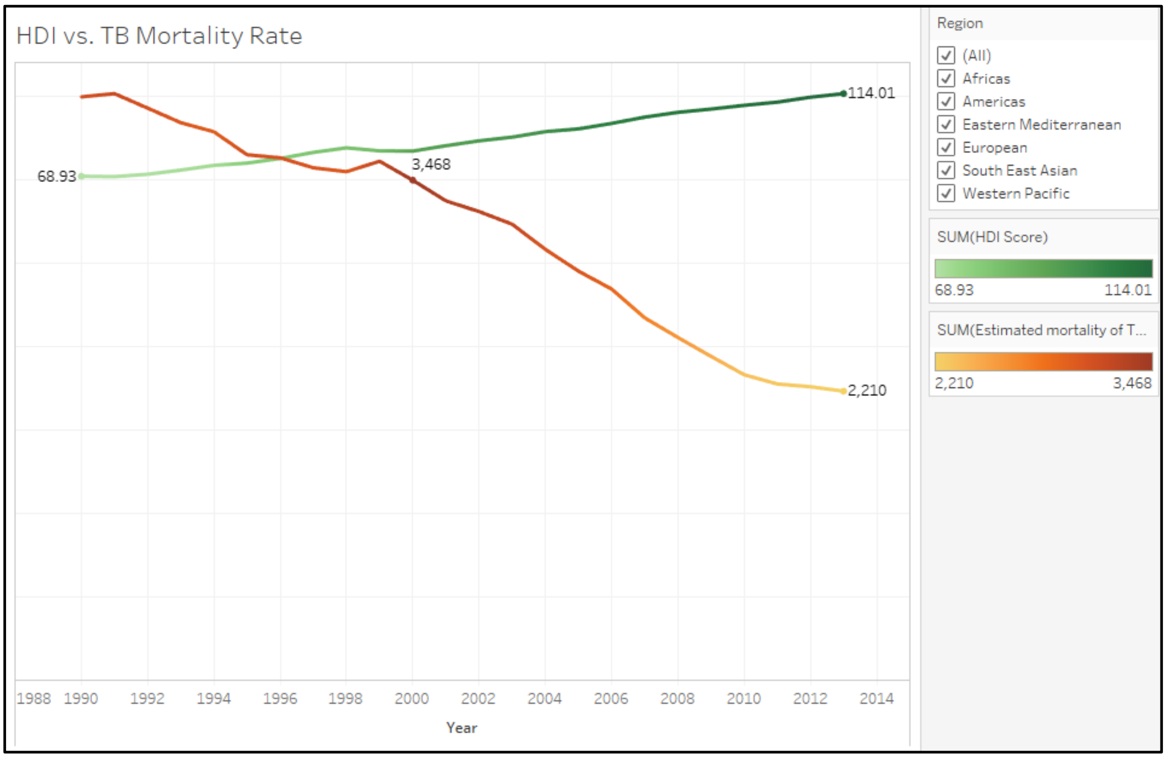


Figure 35: Line Plot - HDI vs. TB Mortality Rate

3) GDP vs. TB Incidence

This visualization compares how global economic growth has coincided with a decline in TB incidence rates. The average global GDP per capita stands at $9,592, while the average estimated TB incidence rate is 145 cases per 100,000 people. By 2013, GDP per capita increased to $15,079, and the TB incidence rate fell to 119 cases per 100,000, indicating a strong correlation between rising economic stability and lower TB incidence. As GDP per capita rises, improved healthcare access, better disease surveillance, and enhanced living conditions contribute to reducing TB cases

There is a need of collective international community assistance for countries with low GDP to strengthen healthcare systems, invest in TB screening programs, and increase public awareness to improve TB handling (World Bank, 2023).

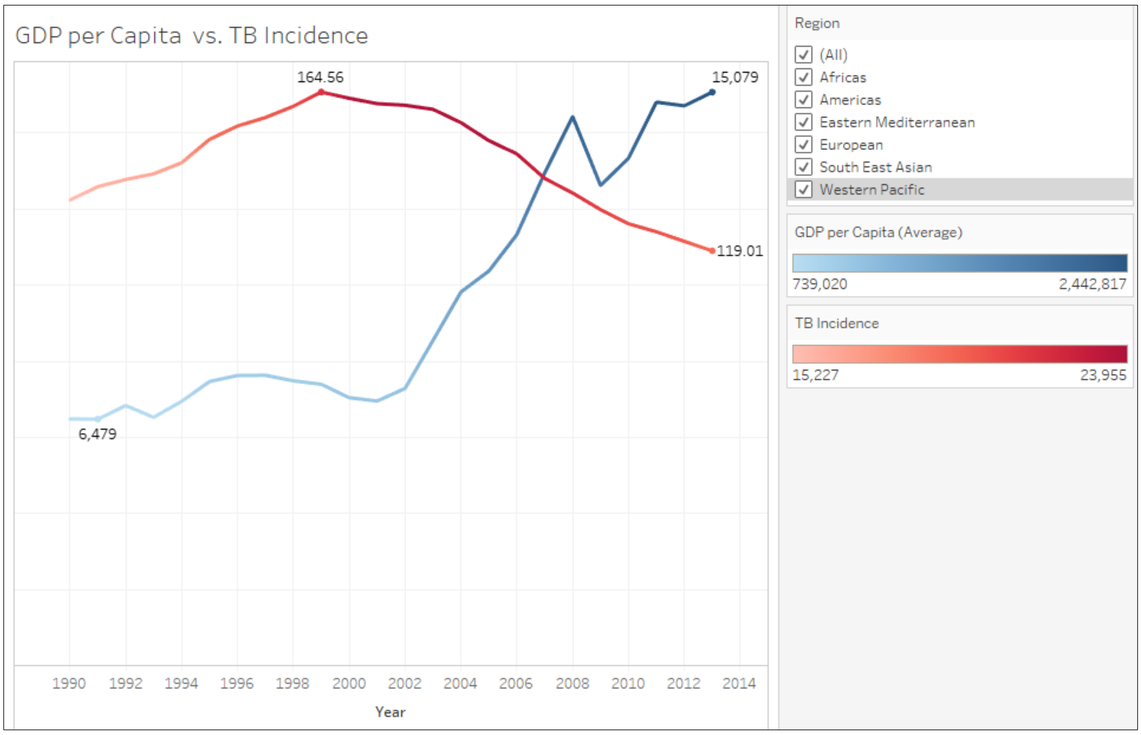


Figure 36: Line Plot - GDP vs. TB Incidence

4) HDI & GDP Correlation with TB Mortality

Below visualizations try to correctly address the nuances with TB mortality and its correlation with prosperity of the country measured in global standard indexes. The bubble chart and bar diagram heatmaps visualize the impact of economic and social development on TB mortality based on the global standards HIGH, MEDIUM and LOW used by World Bank for GDP and The United Nations Development Program (UNDP) for HDI.

Classification	GDP Per Capita (USD)	HDI Score
Low	Below **$4,000**	Below **0.55**
Medium	**$4,000 - $12,500**	**0.55 - 0.70**
High	Above **$12,500**	**Above 0.70**

High-GDP and high-HDI countries have minimal TB mortality, often below 5 deaths per 100,000. Low-GDP, low-HDI countries experience high TB mortality, exceeding 100 deaths per 100,000. Some middle-GDP but low-HDI countries still have elevated TB mortality rates, indicating that social factors like education and healthcare access play a role.

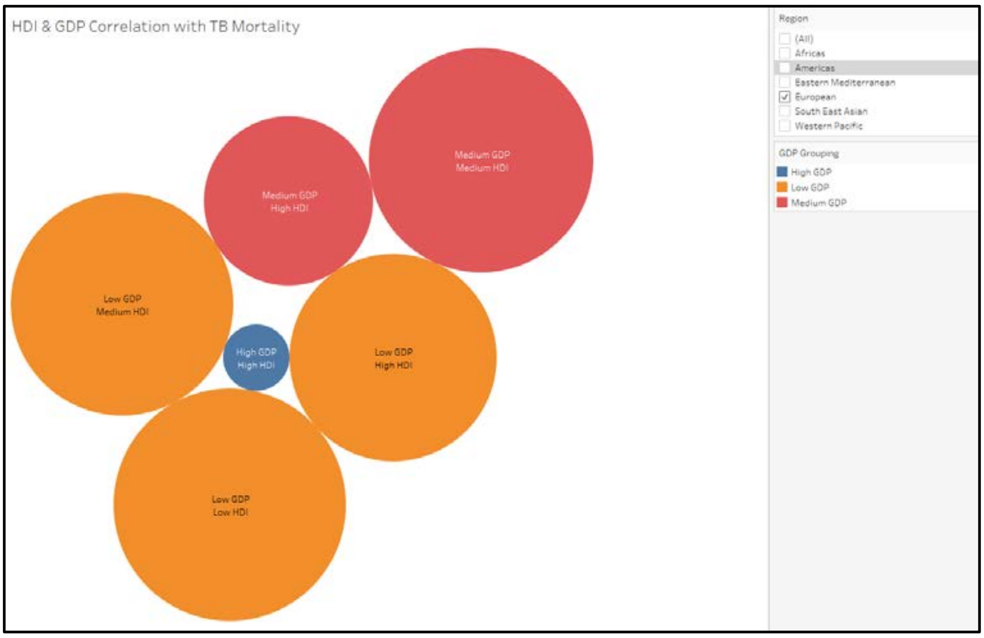


Figure 37: Bubble chart - HDI & GDP Correlation with TB Mortality

Economic growth alone is clearly insufficient as per the data analysis is done. Investments in education, healthcare, and housing are critical to reducing TB mortality (Centers for Disease Control and Prevention, 2023).

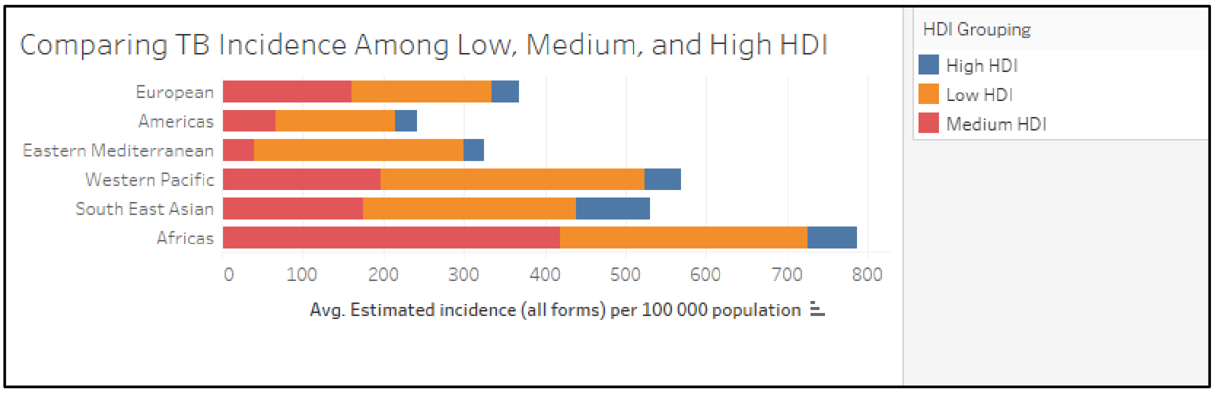


Figure 38: Bar Plot - Comparing TB Incidence Among Low, Medium, and High HDI Countries

The findings from this analysis highlight a hopeful path forward in the global fight against tuberculosis. Economic stability is strongly correlated with lower TB prevalence and better detection rates, demonstrating the crucial role that financial resources play in strengthening healthcare systems. Additionally, higher HDI scores are associated with reduced TB mortality, reinforcing the importance of education, healthcare accessibility, and overall social development.

A holistic approach that combines economic growth with social investments in healthcare, education, and sanitation is critical for sustainable TB control. Countries with lower GDP and HDI scores require targeted interventions that allocate resources effectively where they are most needed. By leveraging data-driven TB control strategies, governments and global health organizations can work towards a future with lower TB incidence, improved healthcare access, and healthier populations worldwide.

VIII. Conclusion

While Sub-Saharan Africa remains one of the regions with high TB incidence, there is a promising opportunity to adopt successful strategies from other parts of the world. Case studies from the Western Pacific Region, Australia, and Singapore such as PRT initiatives and mobile HIV testing demonstrate effective ways to reduce HIV risk. By investing in these approaches and fostering strong collaborations and regional efforts, countries can make significant progress in combating both HIV and TB, ultimately improving global health outcomes.

The secondary analysis reveals a strong inverse relationship between economic development and TB burden. Countries with higher GDP per capita and better HDI scores show lower TB prevalence and mortality rates, emphasizing TB as both a medical and socioeconomic challenge. Wealthier nations generally achieve higher TB detection rates, underscoring the importance of robust healthcare systems and resources. Data collection methods significantly impact reported HIV prevalence, with survey imputation often yielding higher rates than direct testing.

Future improvement

Tableau offers valuable visualizations for analyzing TB patterns but has limitations in advanced predictive analysis. Integrating Python APIs and supervised learning models like Random Forest can enhance predictive capabilities, allowing for more effective evaluation of TB trends and risk factors. Using metrics like recall, sensitivity, and specificity will improve model accuracy and reliability.

While predictions extend to 2018, caution is needed regarding the assumption of a continued decline in TB cases, as historical patterns suggest potential future surges. Future research could focus on comparing TB trends during pandemic and non-pandemic periods, particularly concerning HIV co-infection, to understand the impact of global health crises on TB prevalence and mortality and guide better intervention strategies.

Additionally, demographic factors such as age, gender, and social inequalities play a significant role in managing TB. Addressing these gaps is crucial for tailoring interventions to specific population needs and overcoming social barriers to effective TB control.

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X. Appendices

A. Dashboard

1) Global TB burden Tracker

The Global TB Burden Tracker is an interactive, data-driven dashboard designed for stakeholders to monitor and analyze key TB indicators worldwide. It provides a comprehensive overview of TB-related cases at both global and regional levels, highlighting high-risk regions where the disease burden was most severe.

The dashboard empowers stakeholders to actively participate in End TB strategies Offering insights into TB detection, prevalence, incidence and mortality. It facilitates data-driven decision-making, enabling targeted interventions in high-risk countries and regions.

Key Features of Dashboard

1. **Global Summary Metrics – KPI list table**: Color-coded table describes the total number of TB related cases from year 1990 to 2013.
2. **Geographic TB Burden Distribution – Map:** – An interactive map highlighting regions with the highest TB burden. Users can toggle between different TB indicators (detection, prevalence, incidence, and death) using a dropdown menu.
3. **Top 3 Regional Breakdowns of TB Burden Indicators – Bar Chart:** A bar chart illustrating the top three regions with the highest TB burden. The chart reveals that Africa has the highest rates of TB incidence (72%) and death (98%) with HIV coinfection, indicating a need for increased awareness about TB and HIV diseases, treatment plans and resource allocation.
   Southeast Asia has the highest number of prevalence (407) and mortality cases (39) with non-HIV infection, highlighting the need for stronger preventive measures to control the disease.

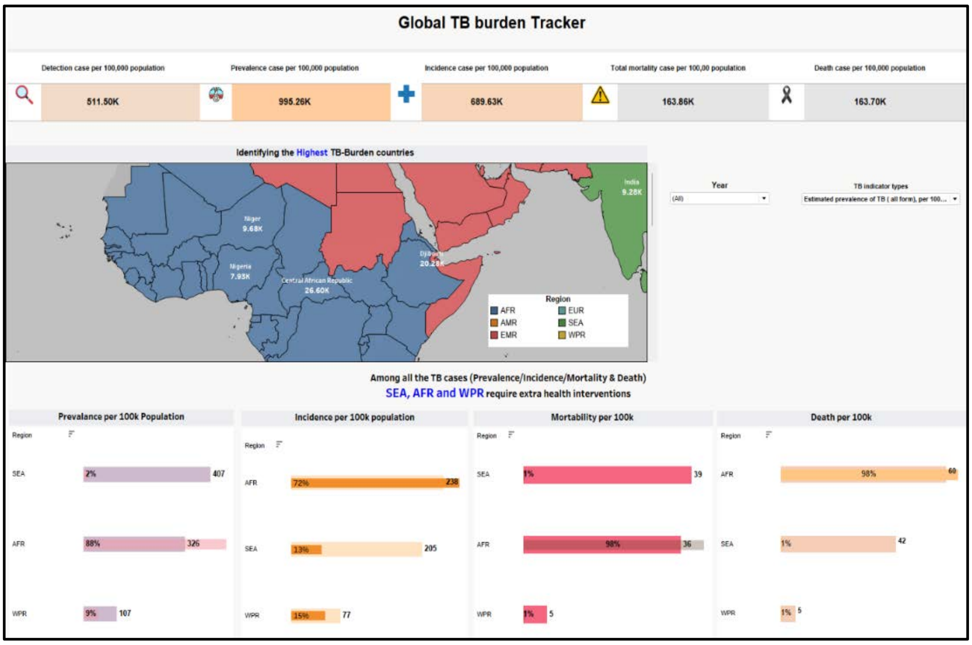

Figure 39: Global TB burden tracker dashboard

2) TB-HIV Case detection Dashboard

The HIV Case Detection Dashboard serves as an interactive tool for stakeholders to monitor, analyze, and understand HIV cases and trends across various regions and countries. By providing comprehensive Year-to-Date (YTD) case detection data, this dashboard enables key stakeholders such as (WHO) to view an overall summary of total cases.

Key Features:

- **Regional Data Segmentation**: The dashboard divides the data by six key regions, each distinguished by a different color, to provide an easy-to-read visual representation of HIV trends. Stakeholders can filter data by region to compare high- and low-burden areas.
- **Data Comparison**: By comparing regions, stakeholders can identify trends and disparities in HIV case detection. For example, they can analyze the difference between high-burden regions like Africa (AFR) and relatively lower-burden regions such as the Americas (AMR).
- The data can also be examined for both all forms of cases and specific HIV cases, helping to strategize interventions.
- **HIV Color Legends:** The color legend provides a visual scale to represent the range of HIV case detections. The legend ranges from 0 to 87, with a gradient color scheme where lighter orange indicates the minimum values, and darker orange represents the highest values.
- As user apply filters to compare regions, the color coding adjusts to reflect the updated data range, making it easier to understand the distribution of HIV cases across different areas.

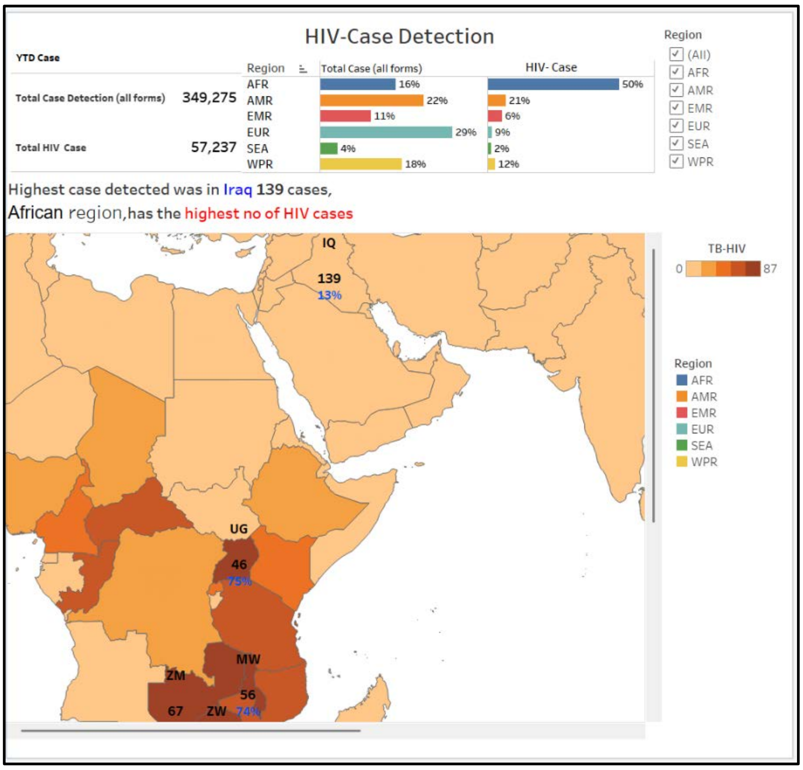

Figure 40: Global TB Detection Case Description Dashboard

3) TB Prevalence Dashboard

The TB prevalence dashboard is designed with interactive features that enhance the ability of stakeholders to analyze and compare HIV prevalence across regions and countries, providing valuable insights for evidence-based policymaking. The dashboard's key features include:

1. **Donut Chart**: This chart presents the total prevalence of HIV, differentiated by colors representing the six WHO regions. It offers a quick visual breakdown of the HIV burden across regions, allowing users to easily compare regional variations.
2. **Global Map**: The map adjusts the size of each country based on its HIV prevalence percentage, allowing users to visualize the global distribution of HIV cases. It shows, for instance, that India accounts for 75% of HIV-related TB cases in Southeast Asia, drawing attention to critical areas for intervention.
3. **Interactive Filters** The interactive filters allow users to select specific regions or countries for comparison, enabling dynamic analysis of HIV prevalence across different areas.

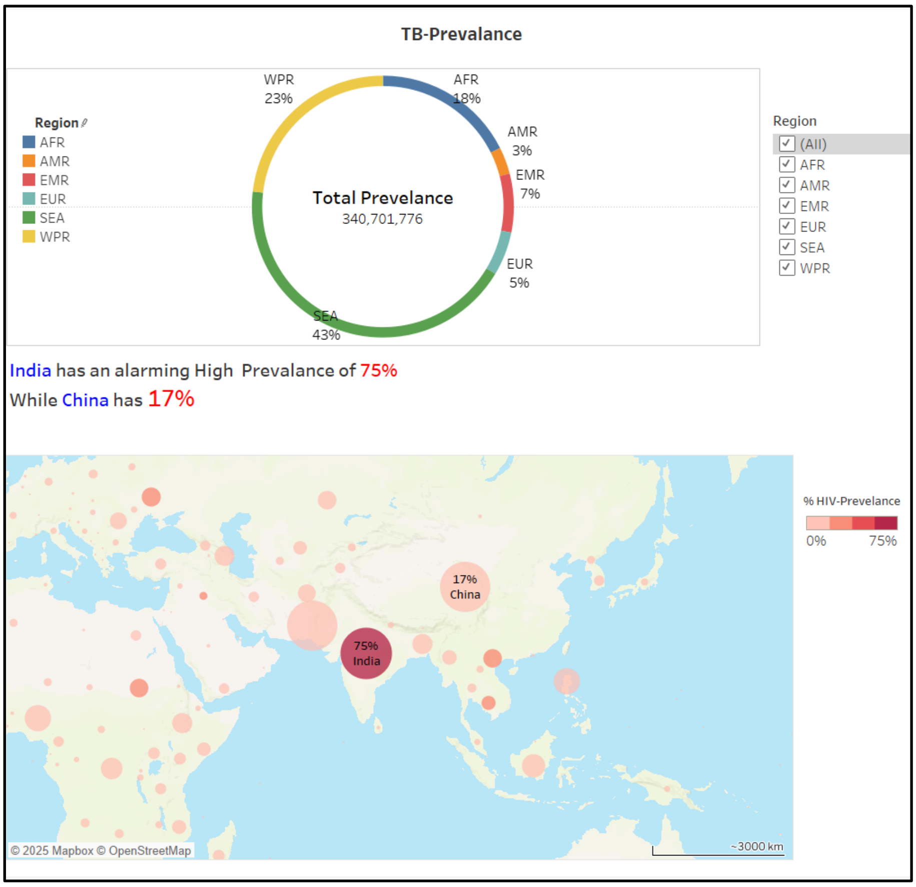

Figure 41: Global TB Prevalence case analysis dashboard

4) TB Incidence Dashboard

This comprehensive dashboard benefits stakeholders by providing both absolute numbers and population-adjusted rates (per 100,000), revealing geographic hotspots, demonstrating disease correlation patterns, and tracking progress over time. Decision-makers can utilize these insights to strategically allocate resources to high-burden areas, design targeted interventions (particularly in regions with high TB-HIV co-infection), monitor program effectiveness through trend analysis, develop evidence-based policies, prioritize research in concerning regions, evaluate intervention impacts, and facilitate cross-border collaboration where needed.

Key Features

- **Global Incidence Map**: Geographical visualization of TB burden across countries, with color intensity indicating incidence rates.
- **Top 10 Incidence Countries**: Bar chart displaying countries with highest absolute TB case numbers.
- **TB-HIV Correlation**: Scatter plot revealing the relationship between TB and HIV incidence rates across regions.
- **Historical Trends and Projections**: Line graphs tracking regional TB incidence from 1990-2018 with future estimates, showing both actual data and forecasted trends.
- **Interactive Filtering:** Interactive filters allowing stakeholders to focus on specific geographic areas and years of interest.

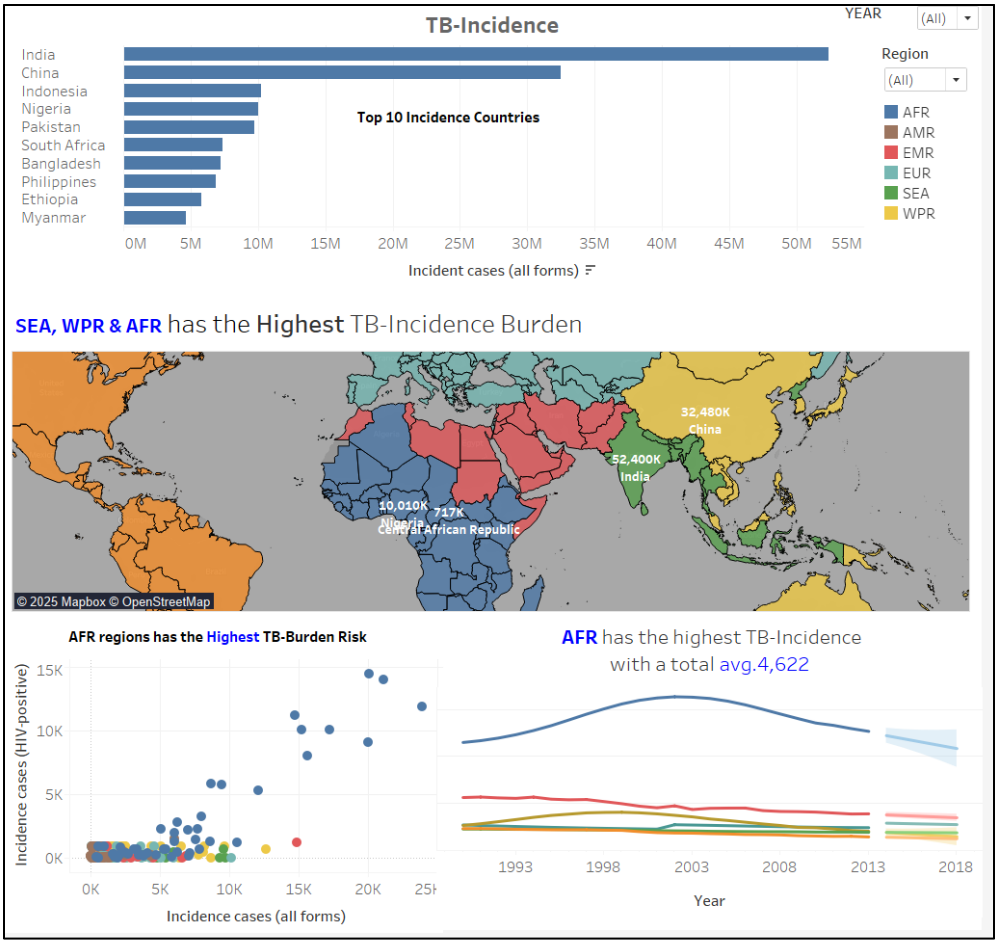

Figure 42: Global TB Incidence case dashboard

5) TB Mortality Dashboard

The TB-Mortality Dashboard is a crucial tool designed to provide policymakers, researchers, and health authorities with comprehensive insights into the distribution of TB-related mortality by geographical region. This dashboard offers a dynamic and interactive platform to analyze trends, identify high-risk regions, and evaluate the effectiveness of health strategies.

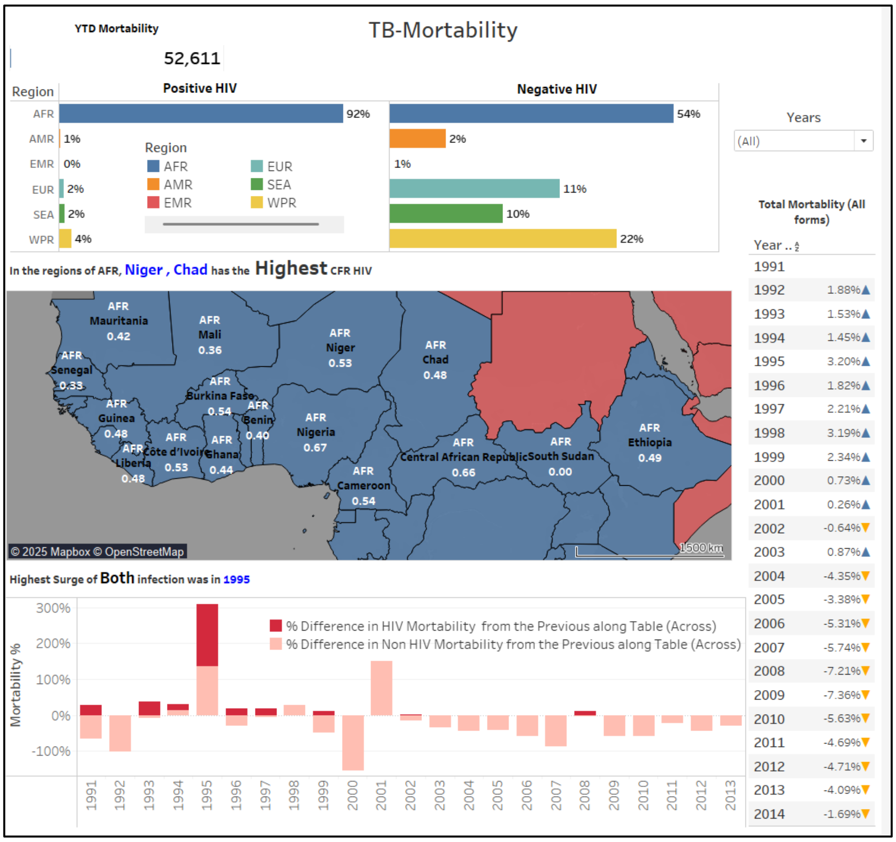

Figure 43: Global TB Incidence Trend analysis dashboard

Key Features of the Dashboard

1. **Filter by Year:** The dashboard allows users to filter data by specific years, providing granular insights into how TB and HIV mortality have evolved over time and across different areas.
2. **Trend Indicators and KPIs:** The dashboard integrates Key Performance Indicators (KPIs) to measure the progress in reducing or increasing TB and HIV-related mortality. The dashboard also calculates the **cumulative percentage change** over a period. For instance, beginning with 1991 as the base year (0), users can track the cumulative changes such as a 1.88% increase in 1992 and a 0.64% decrease by 202. This helps stakeholders assess long-term trends and identify areas for improvement in health interventions.
3. **Global Map and Heatmap:** A global map provides a visual representation of TB mortality distribution worldwide, with regions color-coded by CFR (HIV)
4. **Waterfall Chart:** The waterfall chart provides a visual representation of HIV and non-HIV-related mortality over a twenty-three-year period. This allows users to quickly compare mortality trends, highlighting both high and low mortality periods. The chart aids policymakers in identifying changes in mortality rates, which can help guide public health strategies.

6) TB Death Dashboard

A TB Death case Dashboard has been developed to visualize the recorded number of TB-related fatalities both with and without HIV co-infection from 1990 to 2013. The dashboard is designed to help stakeholder analyze the data effectively and gain a clear understanding of TB-related deaths, so that stakeholder can improve their strategies to fight against with Tuberculosis and focus on countries which encountered the highest Tb death cases.

Key Featured of the Dashboard

1. **Global Summary Metrics (KPI Sections):** to provide a quick view of total number of deaths with HIV and non-HIV.
2. **Geographic TB Death Burden:** to indicate the percentage value of TB death case (all form) filtering with region and year.
3. **Regional TB death cases comparison:** to describe the regions which had the highest and lowest number of death cases.
4. **TB death rate over time (1990 - 2013**): to compare YoY % difference in TB death rates and Yearly risk of death from TB case with HIV and non-HIV in percentage form.

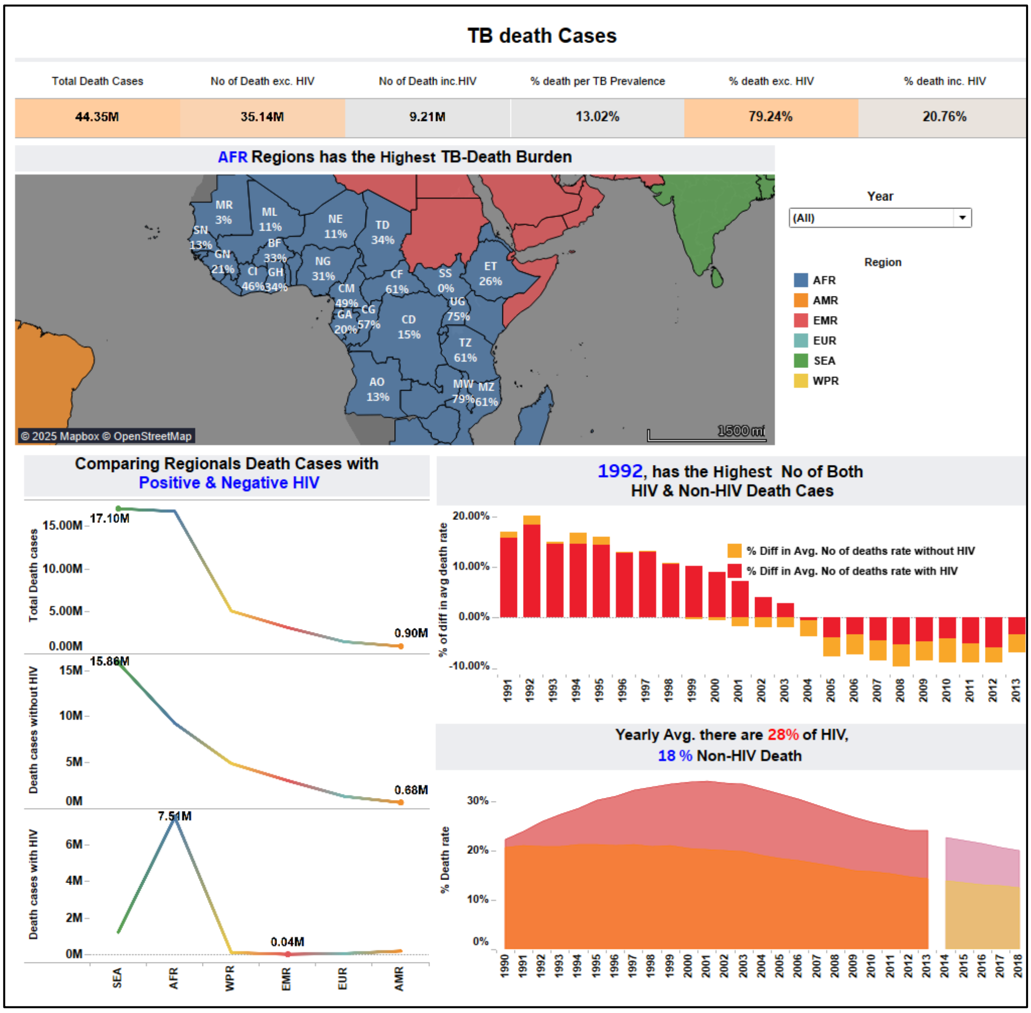

Figure 44: Global TB Death case monitoring dashboard

Global Summary Metrics (KPI section) - Color Highlighted table: The first panel of the dashboard features a color-highlighted table that provides a comprehensive breakdown of global TB-related fatalities. It distinctly illustrates what are the total number of global TB-related deaths (both with and without HIV co-infection) and proportion of global TB TB-related deaths case, highlighting the percentage of fatalities attributed to TB with HIV and without HIV impacted cases from 1990 to 2013. Thus, it allows stakeholders to easily interpret the distribution and impact of TB fatalities over the recorded 13 years periods.

Geographic TB Death Burden – Map: The map visualization of TB-related fatalities uses a colour gradient, where lighter shades indicate a lower number of deaths, while darker shades represent higher fatality rates. This visual approach allows for an easy identification of countries with the highest TB-related deaths.

Additionally, the map is labelled with number of total deaths from TB case linked with HIV and without HIV impacted and percentage of death from TB related with HIV co-infection case. It focuses to provide a clear illustration of the global distribution of TB fatalities across the countries.

Regional TB Death Case Comparison - Line Graph: The line graph visualizes the regional TB-related death case with HIV and without HIV co-infection. A range of different color is used to present each region, making it easier to identify with the trend. The line graph effectively highlights which regions rank highest in TB-related deaths, with noticeable spikes along the curves.

The trends reveal that Southeast Asia have the highest TB-related fatalities without HIV co-infection while Africa showing a significant peak in TB cases with HIV co-infection. Therefore, this visualization clearly distinguishes the regional distribution of TB-related deaths, helping to identify which region suffered most from TB-related death.

YoY TB death rate over the time - Bar Chart: The bar chart illustrates the annual comparison of the average number of deaths, both with and without HIV impact. Different colors are used to distinguish between TB death cases with and without HIV co-infection.

This effectively highlights the decreasing trend in deaths over the 13-year period and clearly shows where the significant drops and increases occurred.

Yearly risk of death from TB cases - Area Graph: The area graph describes the risk of death from TB with and without HIV co-infection using the color-coded stacks, presented in percentage format. It covers past trends over 13 years and included the 5- years predictive insights. This visualization approach makes it easy to compare the trends over the times where the smooth progression of the shaded areas clearly shows how death rates has changed from 1990 to 2013 and the expected trend from 2014 to 2018.

This graph highlights differences using the distinct color segmentation to identify the difference between TB cases with and without HIV co-impacted, making it obvious that TB case with HIV has consistently higher fatality rates. Moreover, it forecasts the decline risk of death from TB case (all form) from 2014 to 2018, helping the stakeholders anticipate trends in TB-related mortality.

Additionally, the horizontal lines and percentage markers help to emphasize the average risk of death over time, making the data more visible immediately.

7) TB Correlation Analysis Dashboard

The purpose of this dashboard is to analyze the relationship between **Estimated HIV in Incident TB (percentage)** VS **Estimated TB Incidence per 100,000 population, Estimated TB Prevalence per 100,000 and Estimated Mortality per 100,000 population** This correlation analysis helps in understanding whether an increase in TB incidence is associated with a higher percentage of HIV-positive TB cases.

Each sheet in the dashboard consists of three key visualizations:

1. **Scatter Plot**
2. **Trendline**
3. **Summary Statistics Panel** – Presents the R-squared value and p-value to quantify the correlation.

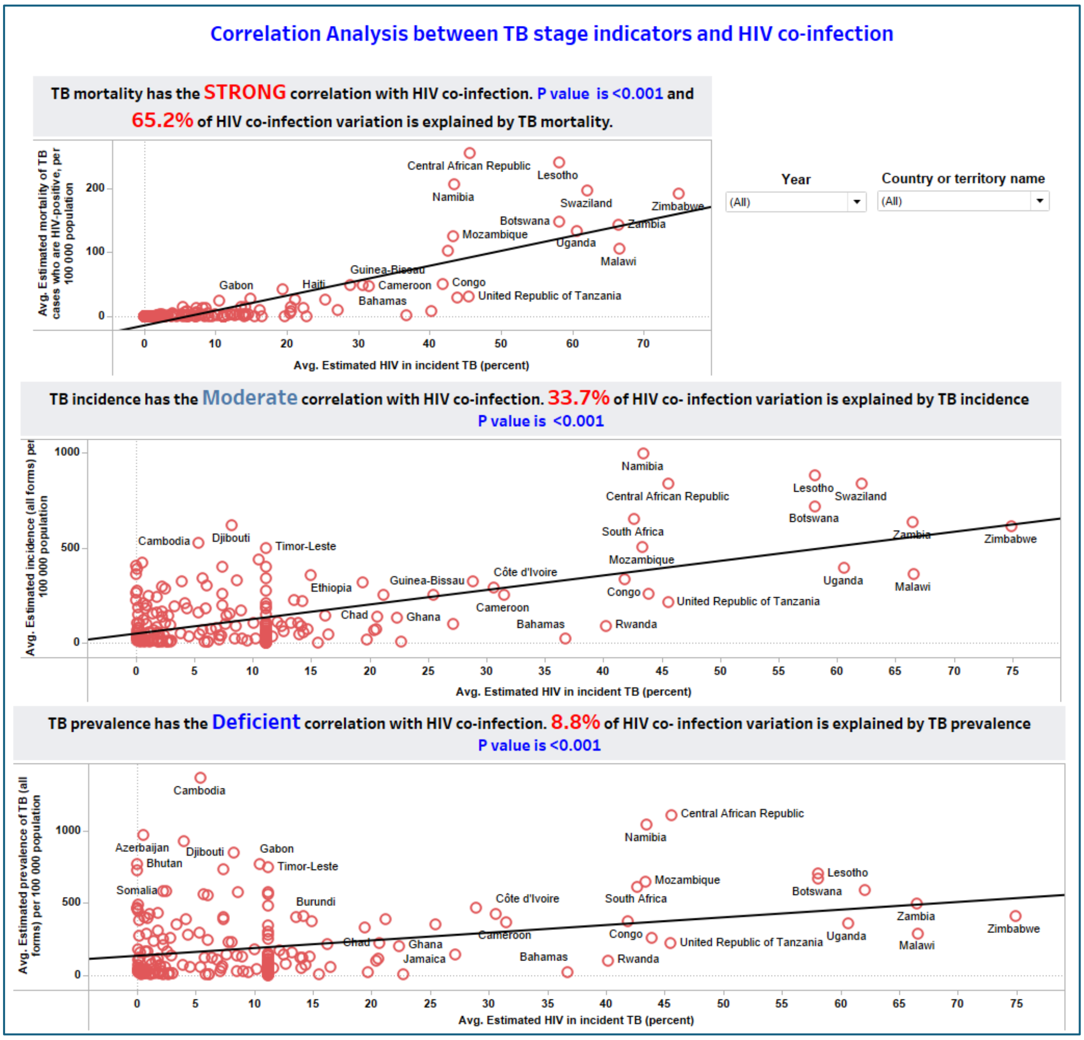

Figure 45: TB Correlation analysis between TB stage indicators and HIV co-infections

Dashboard Components and Analysis

Scatter Plot:

This scatter plot visualizes the distribution of data points, where:

- **X-axis:** AVG (Estimated HIV in incident TB (percent))
- **Y-axis:** Estimated Incidence of TB cases, Estimated Prevalence of TB cases and Estimated Mortality of TB cases.

Trendline: Direction of Correlation

*The trendline in the dashboard represents the **linear relationship** between the two variables. The positive slope of the trendline confirms a **positive correlation**, meaning that:*

- Regions with higher TB incidence, higher TB prevalence and higher TB mortality tend to have a **higher percentage of HIV-positive TB cases**.
- Conversely, regions with lower TB incidence, lower TB prevalence and lower TB mortality tend to have a **lower percentage of HIV-positive TB cases**.

In all three cases our trendline shows upward direction which is a positive correlation.

Summary Statistics Panel: R-Squared and p-Value

- ➢ TB incidence vs HIV co infection rate:

R-square 0.337239 (Indicates a **moderate correlation** (33.7% of the variation in HIV co-infection is explained by TB incidence).

p value: 0.0001(Statistically significant relationship.)

- ➢ TB Prevalence vs HIV co infection rate:

R- square 0.0880849 - **Weak correlation** (only 8.8% of HIV co-infection variation is explained by TB prevalence).

p value: 0.0001(Statistically significant but not strong.)

- ➢ TB Mortality vs HIV co infection rate:

R-square 0.651919 - **Strong correlation** (65.2% of HIV co-infection variation is explained by TB mortality).

p value: 0.0001(Highly significant relationship)

Interpretation: HIV co-infection is strongly linked to TB mortality, meaning HIV-positive TB patients have a higher risk of death.

Limitations and Future Considerations:

While the dashboard provides valuable insights, there are some limitations:

- The **R^2 value suggests that other variables** (e.g., healthcare access, socio-economic factors, or regional policies) might also influence HIV-positive TB cases.
- The analysis assumes a **linear relationship**, but there may be non-linear patterns or interactions with other variables that are not captured in this model.
- Future work can include **multivariate regression models** to incorporate additional predictors for a more comprehensive analysis.

Conclusion:

The Correlation Analysis Dashboard effectively visualizes the relationship between TB incidence, TB prevalence and TB Mortality and HIV-positive TB cases.

The strongest concern is the link between **TB mortality and HIV co-infection**, highlighting the need for **integrated TB-HIV treatment and prevention efforts** to reduce fatalities.

The findings indicate a **positive, and statistically significant correlation**, emphasizing the need for integrated healthcare interventions targeting TB and HIV co-infections. Further research incorporating additional influencing factors could provide deeper insights for policy development and healthcare strategies.

Benefiters From this dashboard:

This dashboard is useful for **public health officials, researchers, and healthcare organizations** working to control **TB and HIV co-infections**.

- **Public Health Officials & Policymakers** → Helps design **better health policies** and allocate resources to high-risk areas.
- **Doctors & NGOs** → Supports **early diagnosis and treatment** for patients in vulnerable communities.
- **Epidemiologists & Researchers** → Provides **data-driven insights** to study disease patterns and risk factors.
- **Global Health Organizations (WHO, CDC, UNAIDS)** → Aids in monitoring **infection trends** and improving intervention strategies.

8) TB burden & Socioeconomic Indicators Dashboard

This interactive dashboard provides insight to the relationship between tuberculosis (TB) and socioeconomic indicators such as Gross Domestic Product (GDP) per capita and the Human Development Index (HDI). Through four key visualizations, the dashboard helps identify how economic stability, human development, and healthcare efficiency influence TB mortality, incidence, and detection rates globally.

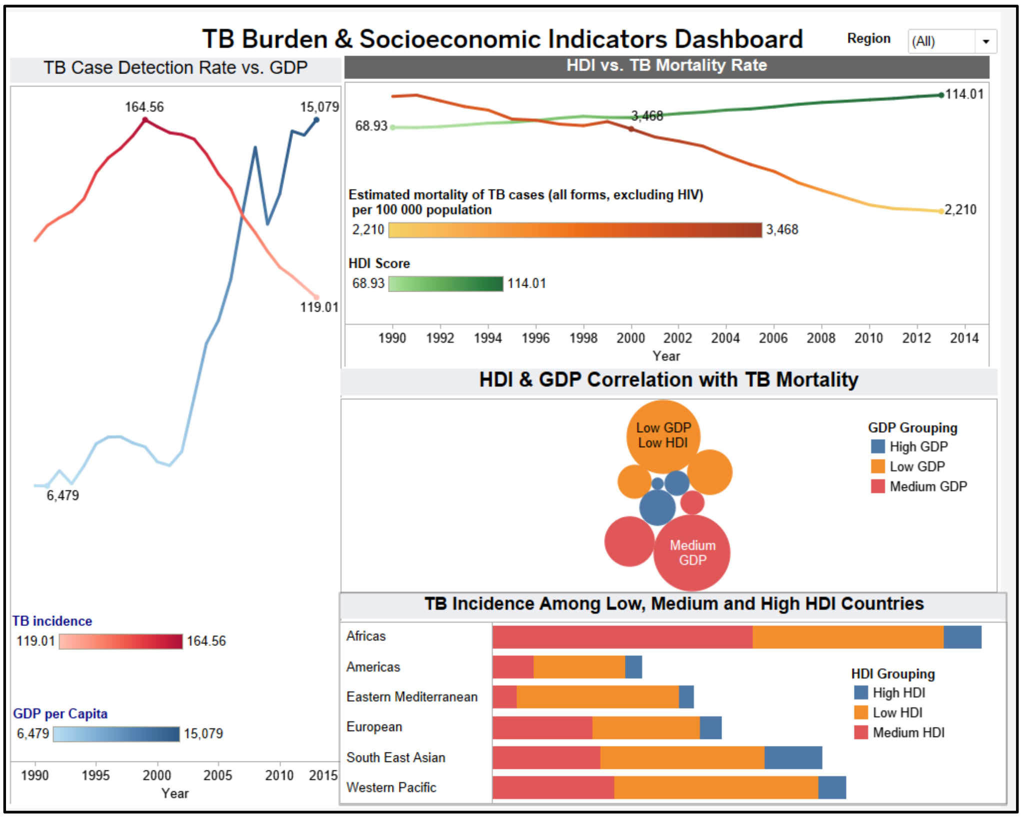

Figure 46: Global TB burden and Socioeconomic Indicator Dashboard

Key Features

- **HDI & GDP Correlation with TB Mortality:** Highlights the correlation between a country's economic standing and human development index with TB mortality rates.
- **Comparing TB Incidence Among Low, Medium, and High HDI Countries:** Categorizes countries based on their HDI levels to analyze their TB incidence rates per 100,000 population
- **TB Incidence vs. GDP:** Examines the relationship between GDPs per capita of countries and TB incidence rates (per 100,000 population).
- **Human Development Index (HDI) vs. TB Mortality Rate:** Explores the direct impact of human development on TB mortality over the years.

B. Additional Features

Summary:

Total number of HIV cases with respect to PREVALENCE, INCIDENCE AND MORTALITY

- Total Parameters used: 4

Common parameter for all three visualizations is X- Axis - Estimated HIV in incident TB (percent)

Explanation of parameters:

According to the analysis,

- The X axis is represented as Estimated HIV in incident TB (percent)

What does this parameter mean?

This parameter tells us how fast the new HIV infections spreads in a population over a specific period. Aim is to measure the rate of new HIV cases in a community or a country.

HIV INCIDENCE PERCENT FORMULA =

$$\text{HIV Incidence Percent} = \left(\frac{\text{New HIV Cases}}{\text{Total Population at Risk}} \right) \times 100$$

Where:

- **New HIV Cases**: The number of people who have been newly diagnosed with HIV in a certain time (e.g., a year).
- **Total Population at Risk**: The number of people who could potentially be infected, like all adults in a certain region or a specific group of people.

Importance of the parameter:

- **Parameter 1: HIV incidence percent** is important because it shows how quickly HIV is spreading in a community.

Here's why it's crucial:

1. **Tracks HIV Spread**: It helps us see if the virus is spreading faster or slowing down over time.
2. **Guides Prevention**: A high incidence means more action is needed—like better education, testing, and prevention methods.
3. **Allocates Resources**: Knowing the rate helps direct funds and resources to areas or groups at higher risk.
4. **Monitors Health Efforts**: A decrease in incidence shows prevention programs are working; an increase means we need to adjust strategies.
5. **Early Warning**: If the rate rises, it signals a possible outbreak, prompting quick action.

6. **Improves Health**: It helps shape policies and treatments to reduce new infections and improve care for those affected. In short, tracking HIV incidence helps prevent new infections and guides how we respond to HIV in communities and helps in stop spreading HIV cases.

Yes, the **HIV incidence percent** is an important parameter for **correlation analysis with the incidence rate**. Here's why:

1. **Identifies Relationships**: Correlation analysis helps identify how different factors (like risk behaviors, access to healthcare, or prevention programs) are related to the HIV incidence rate. If there's a strong correlation, it indicates that certain factors are influencing the rate of new HIV infections.
2. **Monitors Trends**: By analyzing the relationship between HIV incidence and other variables, we can track how changes in one factor (such as increased awareness or policy changes) impact the incidence rate over time.
3. **Guides Public Health Strategies**: Understanding the correlations allows health organizations to focus on specific factors that are driving higher incidence rates, like age, gender, or geographic location.
4. **Improves Prevention**: If we can correlate incidence rates with factors like testing frequency or treatment access, we can improve targeted prevention efforts.

In summary, analyzing correlations with the HIV incidence rate is crucial because it helps uncover the factors affecting the spread of HIV and guides more effective strategies to reduce new infections.

- **Parameter 2**: The Y axis is represented with a parameter called **[Estimated incidence (all forms) per 100,000 population]**

What is it?

It refers to the **number of new cases** of a disease (such as HIV) in a population over a specific period, expressed **per 100,000 people**. (It measures how many new cases of the disease occur for every 100,000 individuals in the population. This is useful for comparing the disease's spread in different areas, regardless of their population size.)

Importance of this parameter:

It helps understand the **rate** of new infections within a specific population.

It provides a **standardized measure** to compare disease occurrence between regions or groups, helping public health officials track trends and allocate resources.

- **Parameter 3: Estimated prevalence of TB (all forms) per 100,000 population] :**

Tells us how many people, out of every 100,000, are currently living with tuberculosis (TB) in all its forms at a given point in time. (It shows how widespread TB is in a specific population, whether the cases are new or ongoing.)

Importance:

- It gives a clear picture of how common TB is in a population.
- It helps health officials understand the **overall impact** of TB in a region.
- Knowing the prevalence helps in **planning treatments**, allocating resources, and designing effective prevention strategies.

➢ **Parameter 4:** Estimated mortality of TB cases who are HIV-positive, per 100 000 population

What is it?

This parameter refers to the **number of deaths** from tuberculosis (TB) among people who are also HIV-positive, expressed per 100,000 people in the population.

Importance:

- People with both HIV and TB are at a **higher risk of death** because both diseases affect the immune system, making it harder for the body to fight infections.
- This measure helps health officials understand how **dangerous TB is for those with HIV**, allowing them to focus resources on providing better care for these vulnerable individuals.
- It highlights the **severity of co-infection** and helps improve planning for treatments and prevention strategies aimed at reducing deaths among people living with both HIV and TB.

➢ **Parameter 5: Case fatality rate (CFR) of TB (Ex HIV)**

Helps identify disparities in TB mortality rates across different countries or regions.
The formula is:

([Estimated number of deaths from TB (all forms, excluding HIV)]) / (([Estimated number of incident cases (all forms)]) - ([Estimated incidence of TB cases who are HIV-positive])) * 100

➢ **Parameter 6**: **Case fatality rate (CFR) of TB (HIV)**

A higher CFR_TB_HIV indicates that TB is more deadly among HIV-positive individuals, potentially due to weakened immunity and limited access to antiretroviral therapy (ART). The formula is:

Estimated TB Death in HIV positive/ TB Case in HIV positive

C. ETL Workflow

It is essential to process a well-structured ETL workflow before proceeding with data analysis and visualization. We leverage power query within excel to extract raw data from various sources, clean and transform it to ensure consistency and accuracy, and then load the refined data into Tableau for visualization. This process enables efficient data management and enhances the quality of insights derived from the analysis.

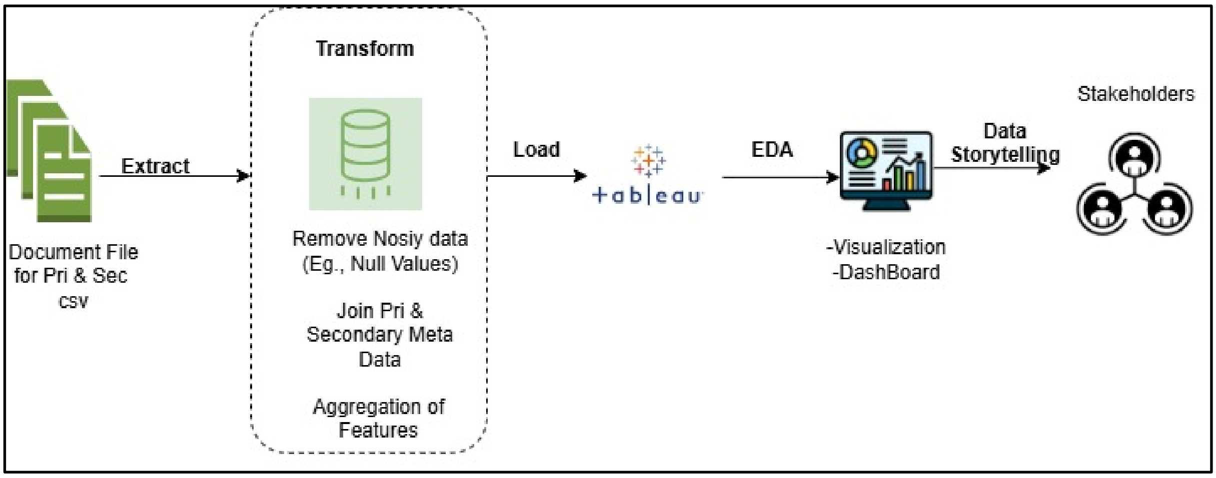

Figure 47: ETL workflow Process

The image above illustrates the ETL workflow process, starting from extracting raw data from the csv file to presenting a visualization dashboard to stakeholders. The ETL workflow consists of three main steps:

1. **Extracting raw data using Power Query within Excel**
   - Open excel workbook and navigate to the Data tab.
   - Click on 'Get Data' and select the "TB_burden_country.csv" file
   - Click on "Load" to establish a connection to the dataset to enable further data transformation.

2. **Transforming Data**
   - Perform necessary data cleaning, such as removing duplicates, handling missing data with replacement such as inserting zero, and standardizing formats
   - Apply transformations like filtering, merging two meta data and aggregating data. For example, combining values from two columns to calculate the cumulative number of TB cases across all forms.
   - Ensure data accuracy and prepare it for seamless integration into Tableau.

3. **Loading Data into Tableau**
   - Import the transformed data into Tableau and join the two transformed Excel files using an inner join based on key attributes such as country, year, and region.
   - Create interactive dashboards by defining necessary parameters and utilizing tableau's built-in features to enhance data exploration.
   - Design effective visualizations that present insights to stakeholders.